MOORED INSTRUMENT OBSERVATIONS FROM BARROW STRAIT, 2010-2011

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by

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Abstract

Pettipas, R. and J. Hamilton. 2015. Moored instrument observations from Barrow Strait, 2010-2011. Can. Data Rep. Hydrogr. Ocean Sci. 195: viii + 89 p.

Instrumented moorings deployed in the eastern end of Barrow Strait from August 2010 to August 2011 provide yearlong records of current, temperature, salinity, and ice drift data, extending a data time series to a thirteenth and final year. The observational program, started in 1998, explores the magnitude and variability of freshwater, heat and volume transports through the eastern Northwest Passage. The presented current and ice drift data were collected with acoustic Doppler current profilers (ADCPs) and specialised instrumentation for near-pole direction measurement. Yearlong records of temperature, salinity and density for fixed depths from moored CTDs are also presented. These current and CTD data are reported as filtered and unfiltered time series, spectral and tidal analyses products, and in statistical summaries. Finally, data from a moored, upward-looking sonar that was also a part of the array this year, are presented in a statistical summary and as monthly histograms of ice draft distribution.

Résumé

Pettipas, R. and J. Hamilton. 2015. Observations des instruments amarrés dans le détroit de Barrow, 2010-2011. Can. Data Rep. Hydrogr. Ocean Sci. 195: viii + 89 p.

Les amarrages équipés installés à l'extrémité est du détroit de Barrows d'août 2010 à août 2011 ont fourni des enregistrements tout au long de l'année de données sur le courant, la température, la salinité et la dérive des glaces, prolongeant ainsi une série chronologique pour une treizième et dernière année. Le programme d'observation, lancé en 1998, examine l'ampleur et la variabilité du transport de l'eau douce, de la chaleur et du volume dans la partie est du passage du Nord-Ouest. Les données présentées sur le courant et la dérive des glaces ont été recueillies à l'aide de profileurs de courant à effet Doppler (ADCP) et d'instruments spécialisés pour la mesure de la direction à proximité des pôles. Les enregistrements tout au long de l'année de la température, de la salinité et

de la densité pour les profondeurs fixes effectués par les sondes CTP amarrées sont également présentés. Ces données sur le courant et les données de CTP sont indiquées sous la forme de séries chronologiques filtrées et non filtrées, de produits d'analyse spectrale et d'analyse de la marée, et de résumés statistiques. Enfin, les données d'un sonar à vision ascendante amarré, qui faisait également partie du dispositif cette année, sont présentées dans un résumé statistique et sous la forme d'histogrammes mensuels de la répartition du tirant d'eau glaciel.

Introduction

A field program to quantify and examine the inter-annual variability of the exchange through Barrow Strait (a principal pathway between the Arctic and North Atlantic Oceans), was started by BIO investigators in August of 1998. Data from the first 12 years of this study, along with a description of the methods used, have previously been reported [Pettipas and Hamilton, 2013a, 2013b, 2013c, 2014, Pettipas et al., 2010, 2008, 2006, 2005; Hamilton et al., 2008, 2004, 2003, 2002]. Described here are moored instrument data from the thirteenth and final year of the study.

Yearlong records of temperature, salinity and density information derived from moored Microcat CTD data are presented as unfiltered and low-pass filtered time series, and also as power spectra. Current rate and direction (from ADCPs and custom pole compasses) are presented as progressive vector plots, unfiltered and low-pass filtered time-depth plots, and as time series plots for depths corresponding to the moored CTDs. Seasonally averaged statistical summaries for both the CTD and current data are provided as graphs and in tabular form. Results of tidal analyses of the current data give tidal amplitudes, phase, and ellipse orientation as a function of depth for each of the 5 main tidal constituents (K1, M2, O1, S2, P1). As done in previous years, separate tidal analyses were attempted for periods of immobile, solid ice cover and periods of open water. However, as was also the case in 2009-2010, results for the immobile ice condition are not reported since there were no periods of sufficient length to allow for reliable analyses at either of our mooring sites.

Ice drift velocity, obtained from the acoustic Doppler current profilers (ADCPs), are presented as yearlong time series. Ice draft data acquired with a moored ASL ice profiling sonar (IPS) are presented as monthly statistics and monthly histograms of ice draft.

Mooring Locations and Description

Five instrumented moorings were distributed at two sites (South and South-Central) on the southern side of Barrow Strait (Figure 1) to provide the data required to extend the volume, freshwater and heat transport time series started in 1998. ADCPs manufactured by Teledyne RD Instruments (TRDI) and precision heading references (Watson Industries, Inc.) were mounted in streamlined buoyancy packages to provide current rate and direction information. The technique used to obtain reliable direction measurements here, where conventional compass technology is inadequate due to the proximity of the site to the magnetic pole, is described in detail by Hamilton [2004, 2001]. The upward looking ADCPs logged average speeds from 100 pings over a 5 minute on-period every 2 hours, and also provided a simultaneous ice drift speed throughout the yearlong deployments. Two 307 kHz Workhorse Sentinel ADCPs (WHADCPs) were used at the South site, one moored mid-depth and the other near-bottom to give near-full water column coverage. At the South-Central site, a 150 kHz Quartermaster ADCP (QMADCP) was moored near bottom to provide current data over almost the entire water column (from 25 m to 235 m depth), and a WHADCP was moored at 76 m depth for coverage of the 10 to 70 m depth interval. Concurrent direction measurements were logged separately with the precision heading reference systems, and have been merged with the ADCP speed data for presentation here. The three WHADCP/compass systems were successfully recovered with full data sets, but the QMADCP only provided data for the first five months of the deployment due to a battery problem. Three SeaBird Microcat CTDs were used to measure temperature, conductivity and pressure every 30 minutes at targeted depths of 40, 80 and 150 m at both sites, as well as one near-bottom at the South-Central site. All of these CTDs provided complete data sets.

An Ice Profiling Sonar (IPS) was moored at the South-Central site to provide the ice draft data presented in this report.

An illustration of the five moorings deployed for 2010-2011 is shown in Figure 2. A summary of the 2010-2011 moorings and instrumentation, including mooring positions, instrument depths and acquired data records, is presented in Table 1.

Data Processing

Current Speed and Direction Data

The 307 kHz Workhorse ADCPs (WHADCPs) were mounted in streamlined buoyancy packages (A2 "SUBs" manufactured by Open Seas Inc.) and set up to measure current relative to the instrument axes, ignoring their own compass information. These instruments were set up to average over a depth interval of 4 m. Current data above 12 m were rejected based on TRDI's standard echo intensity quality criterion. These ADCPs also record ice drift velocity when there is 100% or near-100% ice cover. Two 307 kHz WHADCPs were moored at the South site (where the water depth is ~149 m), at depths of 77 m and 144 m to give near-full water column current measurement coverage. At the South-Central site where the bottom depth is ~ 268 m, a WHADCP was moored at 76 m depth to provide currents over the upper water column. A 150 kHz Quartermaster ADCP (QMADCP) moored near bottom (244 m) provided near full water column coverage, overlapping the range of the 307 kHz unit in the top 75 m.

Direction was provided using an independent compass package mounted in the buoyancy package tail to give the orientation of the ADCP relative to magnetic north. Initiation of a compass sample cycle was triggered by the commencement of the bihourly ADCP measurement by making use of TRDI's "RDS3 interface" to provide a turn-on pulse to the compass. The compass was programmed to take a 10 s sample in the middle of the 5 minute ADCP sampling interval. This conserved compass battery power, and took advantage of previous experience that current direction does not change significantly over 5 minutes at the study location [Hamilton et al., 2003]. Direction records were then adjusted for the variation in magnetic declination using magnetic observatory data from the NRCAN observatory in Resolute to get direction relative to true north.

Vertical excursions of the WHADCPs caused by current drag forces acting on the mooring were small, with dips exceeding 3 m less than 0.3% of the time at both sites.

Moored CTD Data

SeaBird Microcat CTDs were set up to measure temperature, conductivity and pressure every 30 minutes for the yearlong deployments. Instrument dips due to current drag forces acting on the moorings were small. Vertical dip of the 40 m CTDs at both sites exceeded 3 m only 0.3% of the time.

Low-Pass Filtering

Some of the data series presented have been filtered to remove the semidiurnal and diurnal tides using a Cartwright filter. A window length of 130 hours and a high-frequency cutoff of 0.036 cph have been used. In processing of data presented in previous reports, a technique described by Godin [1972] was used where three simple averaging filters were applied in sequence. Although the mean of the resulting filtered data for the Cartwright or Godin methods are nearly identical, the Cartwright filter does a better job at retaining variability on the 1 to 3 day time scale, so has been chosen here.

Tidal Analysis

Harmonic tidal analyses of current data using Foreman's [1978] method are presented for the summer period of broken or no ice cover. At both the South and South-Central sites this open water period was about 8 weeks; Aug 10 to Oct 6, 2010 and Aug 11 to Oct 9, respectively. The period of consolidated landfast ice was too short at both locations this year to allow for tidal analysis in those contrasting conditions. Tidal ellipse axes amplitudes, orientations and phases for the main tidal constituents (K1, M2, O1, P1 and S2) are plotted as a function of depth.

The periodic vector function describing a particular constituent, traces an ellipse over a tidal cycle with major and minor amplitudes defined by the length of the semi-major and semi-minor axes. The major axis amplitude is always positive. The sign of the minor axis amplitude defines the rotation sense of the current ellipse. When positive the

vector traces the ellipse in a counter-clockwise direction; when negative, the rotation sense is clockwise. Ellipse orientation is the angle measured counter-clockwise from east to the semi-major axis. The phase is a measure of the timing of high water referenced to astronomic positions over the Greenwich meridian. Phase is measured counter-clockwise from this chosen reference.

Data Presentation

Yearlong time series of half-hourly sampled temperature, salinity and density from the moored CTDs are shown in Figures 3- 4. Weak freshening is seen at 40 m in the summer and fall at the South site with the strongest signal being pulses of fresher water from early October to mid-December. Freshening is later (early November to mid-January) and more persistent at the South-Central site, with 40 m salinity values about 1 psu lower than winter-spring values. There, late summer/early fall temperature at 40 m was a half degree lower than in the previous year (Pettipas and Hamilton, 2014), exceeding −1°C for only a week. But water near-bottom in fall and winter at the South-Central site was remarkably warmer than in previous years. The average near-bottom water temperature in the winter of 2011 was +0.30°C compared to -0.05°C the previous year, and ranged between -0.62°C and -0.35°C in the 6 years for which we have these data between 2002 and 2009.

Power spectra of the moored CTD measurements (decimated to 2 hour intervals) are shown in Figures 5 and 6. There is significant energy in the diurnal and semi-diurnal bands in the South site salinity, but only in the diurnal band at the South-Central site. For temperature, the strongest variability is seen in the near-bottom record at the South-Central site.

Yearlong progressive vector diagrams using the bi-hourly data from all ADCP/pole compass systems are shown in Figures 7 - 9. Data from both the mid-water and near-bottom instruments at the South side are combined in Figure 7. QMADCP data from the South-Central site (Figure 8) are only reported until Jan 19 when the instrument stopped working due to a battery issue. The mean flow in the upper water column as measured by the WHADCPs (Figures 7 and 9) is generally alongstrait (105°) at the South

site and generally eastward (90°) at the South-Central site. At the South site there are periods in autumn when the alongstrait current is near-zero which in Figure 7 accentuates a cross-strait component in the upper water column as measured by the upper ADCP that is not seen by the lower instrument. However comparison of annual means at 71 m depth where the instrument ranges overlap, demonstrates only a small difference in direction; 9.4 cm/s at 115° and 9.4 cm/s at 105° for the upper and lower South site instruments respectively.

At the South-Central site, the vector plots (Figures 8 and 9) reveal that throughout the water column there is a mean eastward flow for the first few months followed by 3 months of weak westward flow, and then, from late January until recovery (when only measurements in the upper water column are available), flow returns to being predominantly eastward. The extended period of westward flow in fall is unusual, although not unique since similar behavior was measured in the fall of 2007 (Pettipas and Hamilton, 2013b).

Current data are shown as time-depth plots in Figures 10 – 15. Data are presented in along-strait and cross-strait components, where positive values are defined as flow towards 105° and 15° true, respectively. A month of bihourly current data from the South site is presented in Figure 10. Data from the deep and mid-water ADCPs (which were moored 0.34 km apart) have been combined. Bi-hourly data from the South-Central site through most of the water column (QMADCP) and over the top 70 m (WHADCP, moored 1.2 km away) are shown in Figures 11 and 12. These figures reveal the strong tidal nature of the flow. Yearlong records of low-pass filtered data (tides removed) for the 4 instruments are shown in Figures 13-15. As mentioned above, the periods of observed westward and near-zero flow in fall and early winter are unusual. Predominantly eastward currents at this time of year are more typical. The northward current component in deeper water at the South-Central site (Figure 14) is a feature seen in previous years. In these mean flow plots, missing data near the surface in winter are caused by a decrease in the effective range of the ADCPs due to a minimum of acoustic reflectors in the water. The smoothing filter used has smeared the impact of missing data over the filter length.

Smoothed temperature, salinity and current data (where available) are shown for each moored CTD level in Figures 16-22. Tables 2 through 13 provide a summary of the CTD and ADCP data at the CTD depths, with statistics computed over each season, and for the entire year. For the South-Central site, WHADCP data are reported in the tables for the 38 and 56 m levels, while QMADCP data are reported for the deeper levels (154 and 264 m). Density has been included in these statistical summaries.

Annual and seasonal mean flows are summarised in Figures 23-28, where 4 m binned values for the WHADCPs and 8 m bins for the QMADCP are shown. Data from the 39 and 43 m levels at the South site are not shown in these figures because of contamination caused by acoustic interference from the top buoyancy package of the mooring. Late summer and fall along-strait mean currents at both the South and South-Central sites rival those in 2007 as being the lowest over the 13 year monitoring program. Significant cross-strait (northward) currents in deeper water at the South-Central site are evident as usual, appearing in all seasons for which the deep measurements are available. The variance in the bi-hourly, and low-pass filtered current data for the yearlong ADCP records are shown in Figure 29.

Tidal analysis results for each of the 4 ADCP data sets are presented as profiles for the 5 largest tidal constituents in Figures 30 – 44. Analyses have been done for the period of open water only since the immobile ice-cover period was too short to allow for this type of analysis at either site under that ice condition. Ellipse orientations are along-strait as expected. Tidal constants are summarised in Tables 14 – 18.

Ice velocities through the year at both sites were derived from the WHADCPs (Figures 45 and 46). Sections in the record when there are no data indicate periods of open water, or partial ice cover as determined by applying the manufacturer's suggested data quality standards to the ice velocity data. In addition, the ice drift velocity estimate and the adjacent estimates were rejected when the magnitude of the "error velocity" for a particular ensemble was greater than 1 cm/s. Although there was full ice cover for 7 months at both sites, the longest period of immobile ice was less than 4 weeks at the South site, and the ice never stopped moving at the South-Central site. This is similar to what was observed in 2009-2010; more than 8 months of full ice cover at both sites with only a few weeks when the ice became immobile.

Ice draft was measured at the South-Central site for the fifth time in this program, the previous measurement years being 2003-2004, 2005-2006, 2006-2007 and 2009-2010. Monthly mean, standard deviation, and maximum ice draft for 2010-2011 are shown in Figure 47 and Table 19, while histograms of draft distribution by month (based on the data presented in Table 20), are shown in Figure 48. Mean ice draft exceeded 1 m by November, peaked at 2.5 m in January, then dropped back to about 1 meter for April and May. These mean thicknesses were not as large as observed in the previous year but observed monthly maximum ice drafts were comparable, being larger than 15 m for 6 months. The ice draft observations are consistent with what we might expect from an ice pack that was mobile for most of the year. More ice motion leads to more rafting of ice, which results in higher maximum drafts, greater ice volume, and larger monthly mean drafts. It also results in broader monthly distributions of ice draft (Figure 48) compared to years like 2005-2006 (see Pettipas, Hamilton, and Prinsenberg, 2010) when the ice was immobile for almost 6 months. Note that the red bars in the October and November histograms of Figure 48 represent the percentage of missing data in those months.

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Figure 1: **A map of the work area with the location of the two mooring sites identified by the open boxes.**

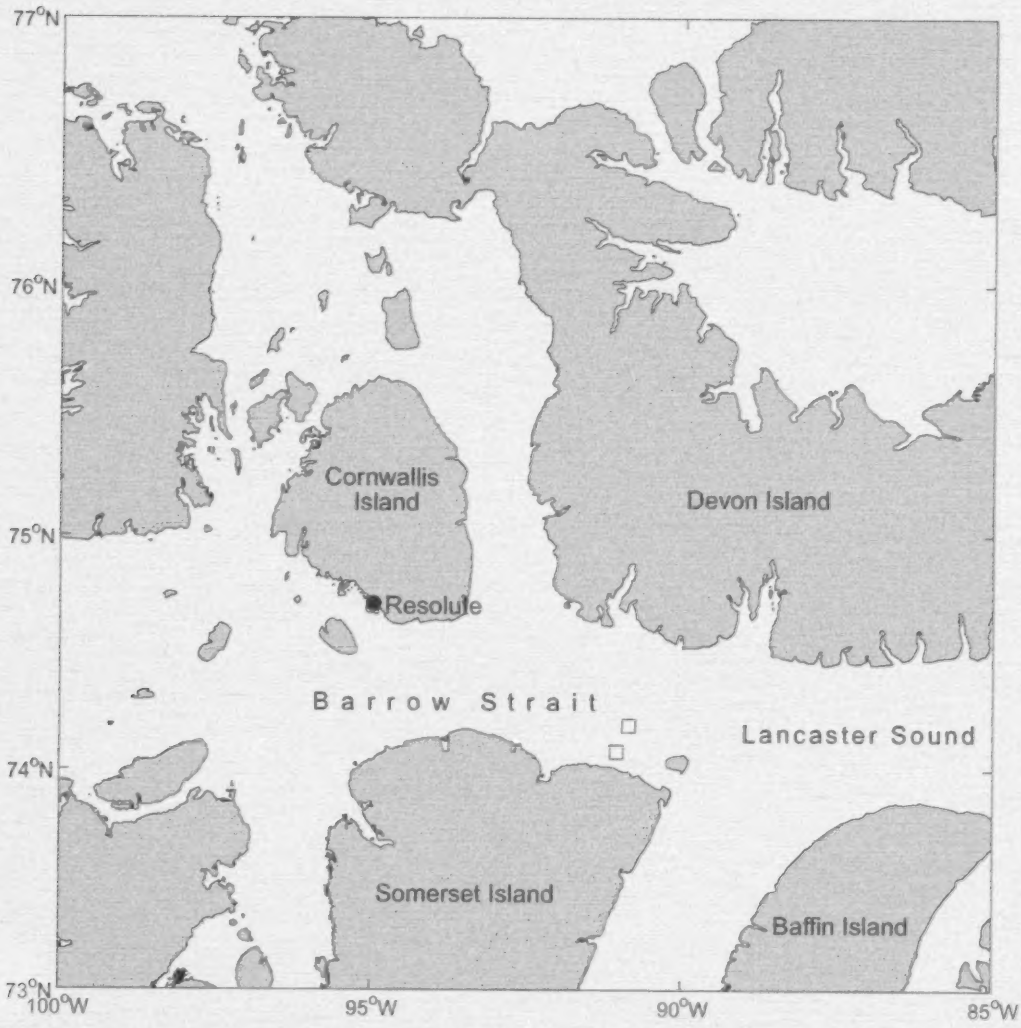


Figure 2: **Illustration of the instrumented moorings.**

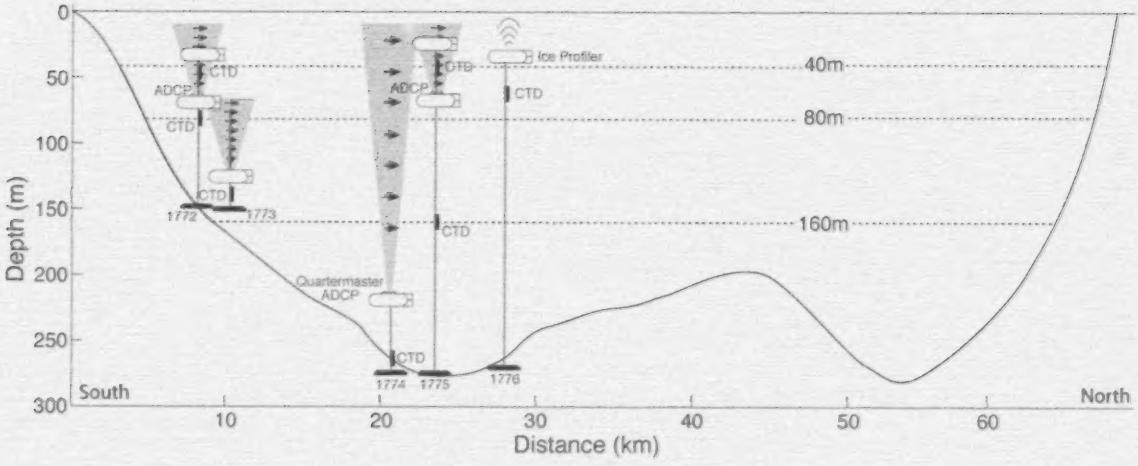


Figure 3: Moored 30 min. CTD data, South Side Barrow Strait. August 2010 – August 2011

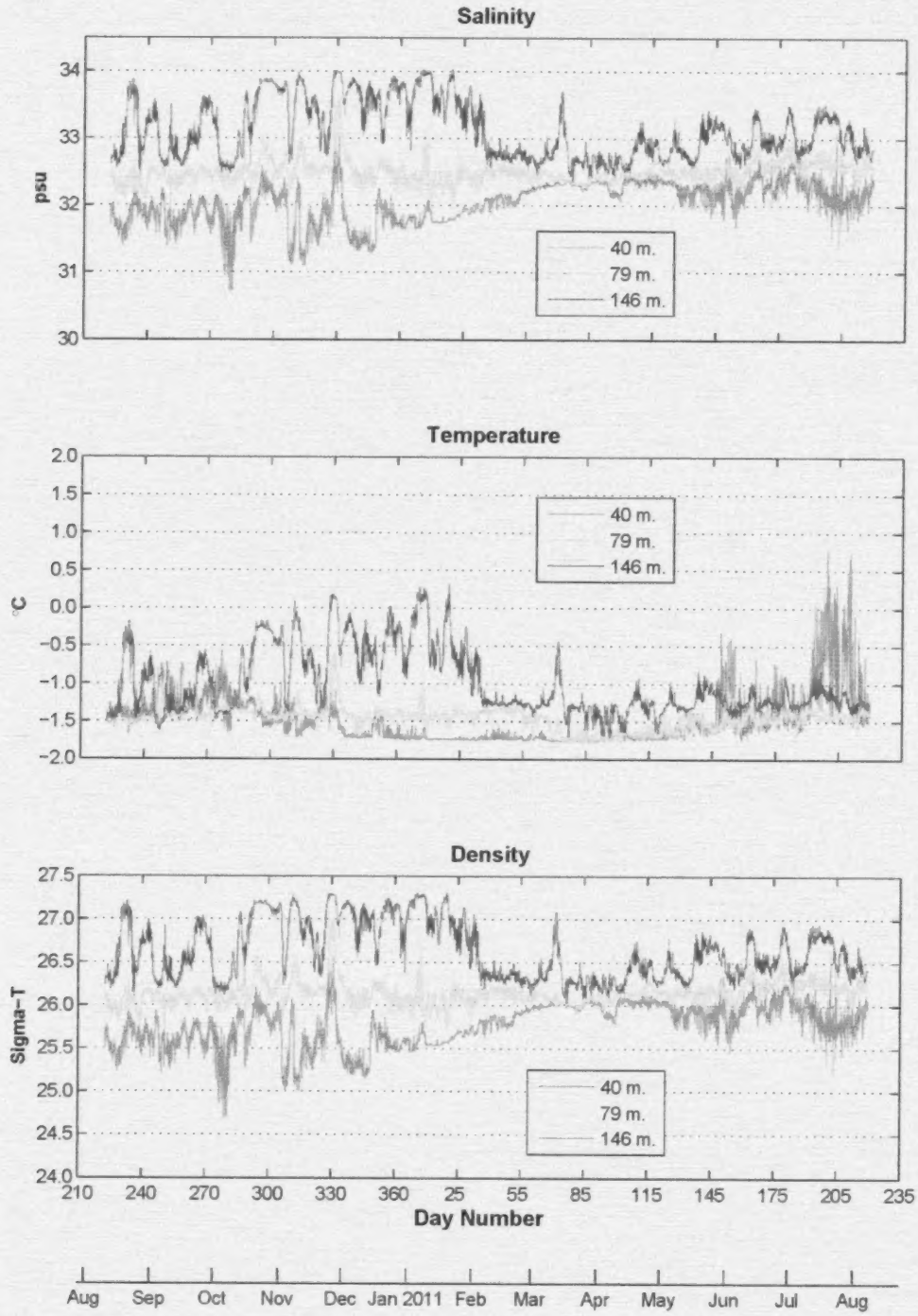


Figure 4: Moored 30 min. CTD data, South Central Barrow Strait. August 2010 – August 2011

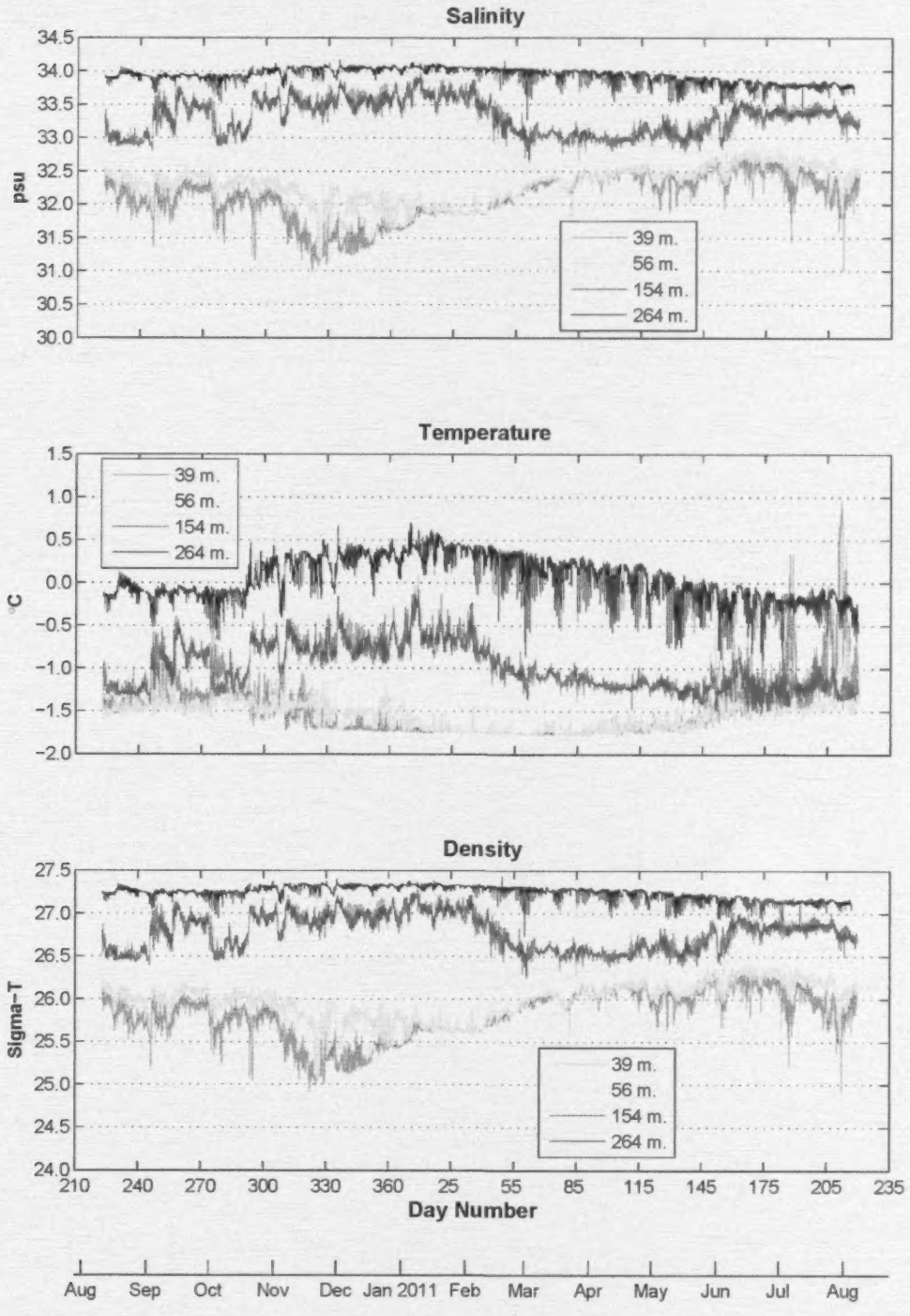


Figure 5: Power Spectra of moored bi-hourly CTD data. South Side Barrow Strait: Aug. 2010 – Aug. 2011.

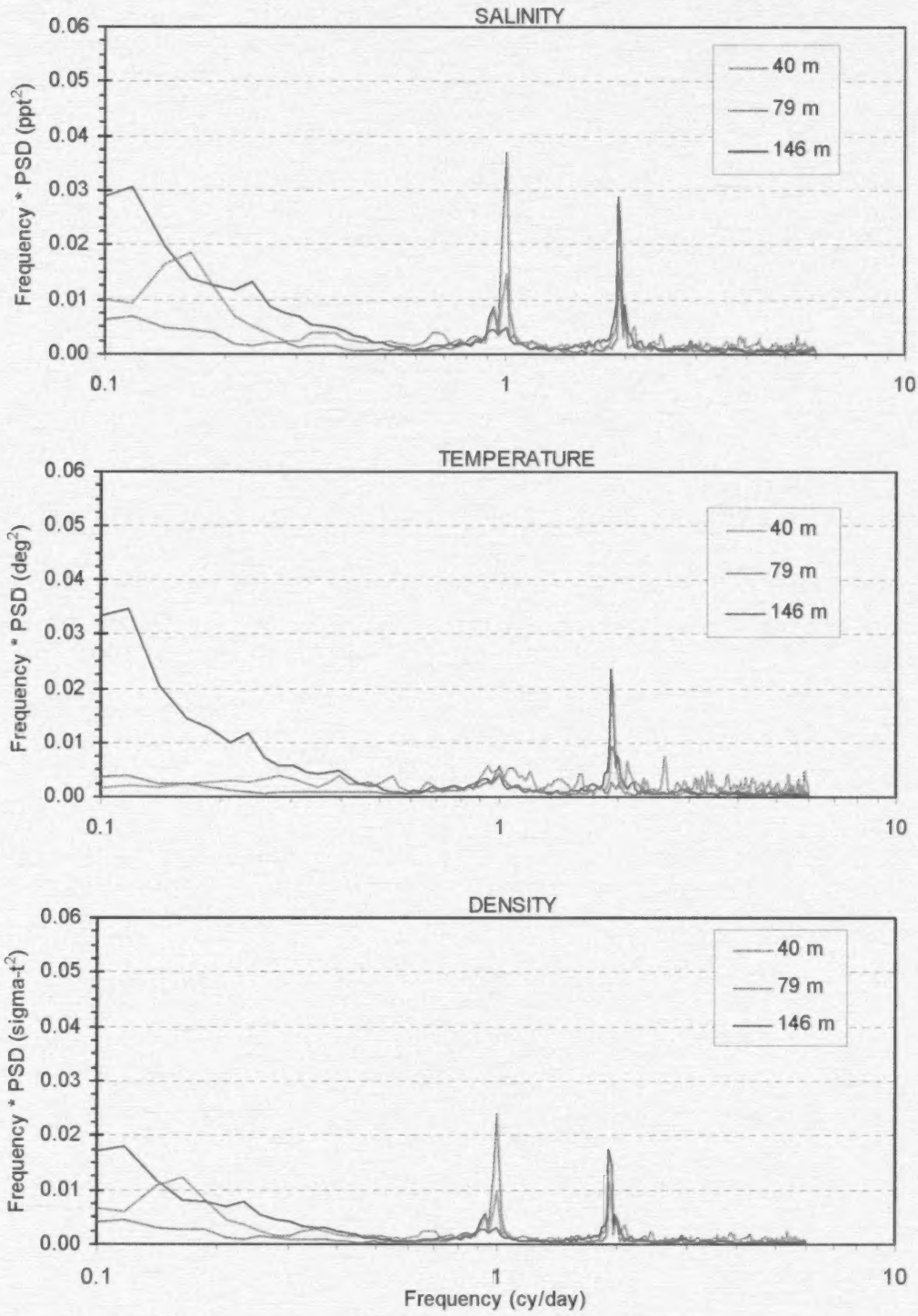


Figure 6: Power Spectra of moored bi-hourly CTD data. South Central Barrow Strait: Aug. 2010 – Aug. 2011.

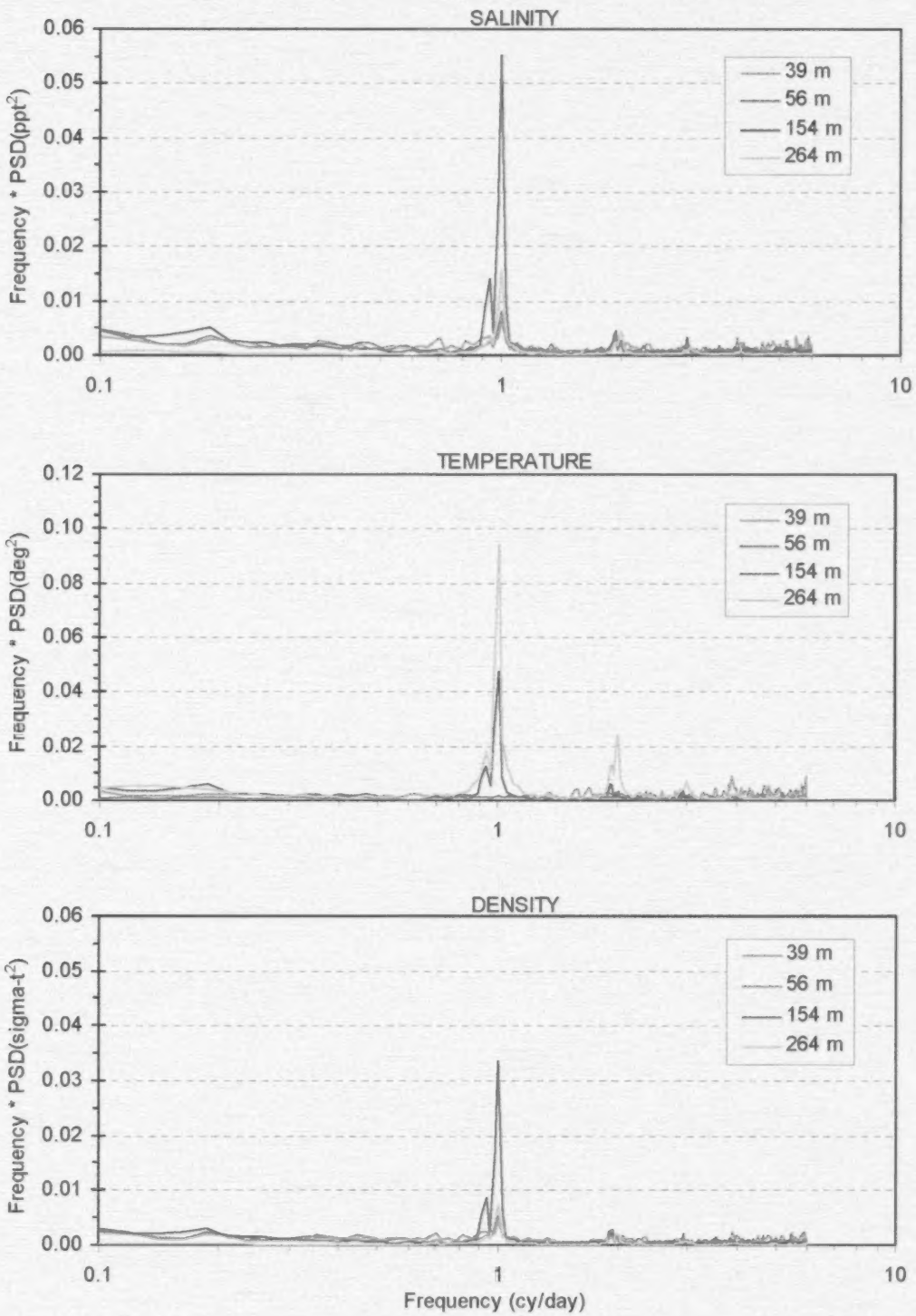


Figure 7: Progressive Vector Diagram, South Side Barrow Strait.
Aug. 10, 2010 – Aug. 7, 2011

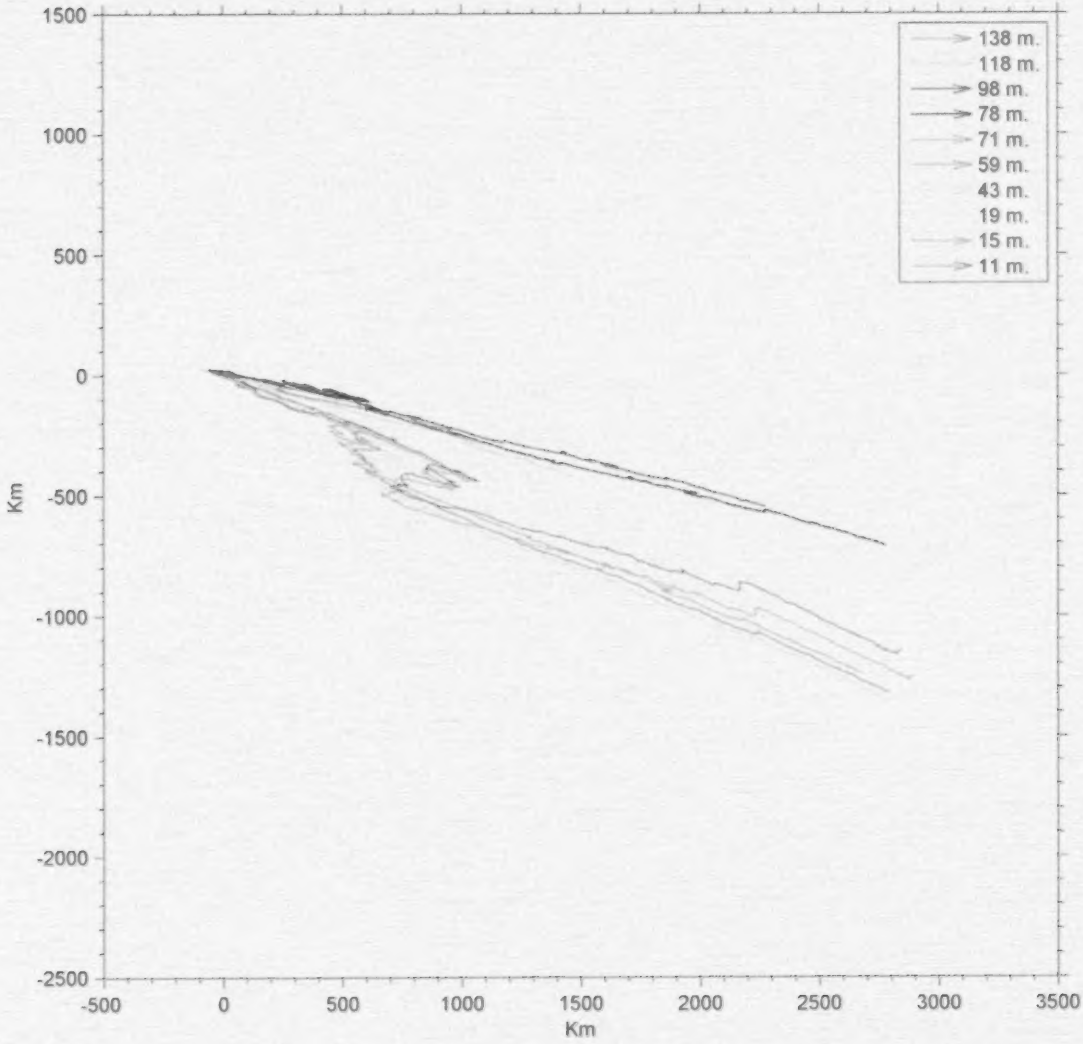


Figure 8: Progressive Vector Diagram, South Central Barrow Strait. (Quarter Master ADCP) Aug. 11, 2010 – Jan. 19, 2011

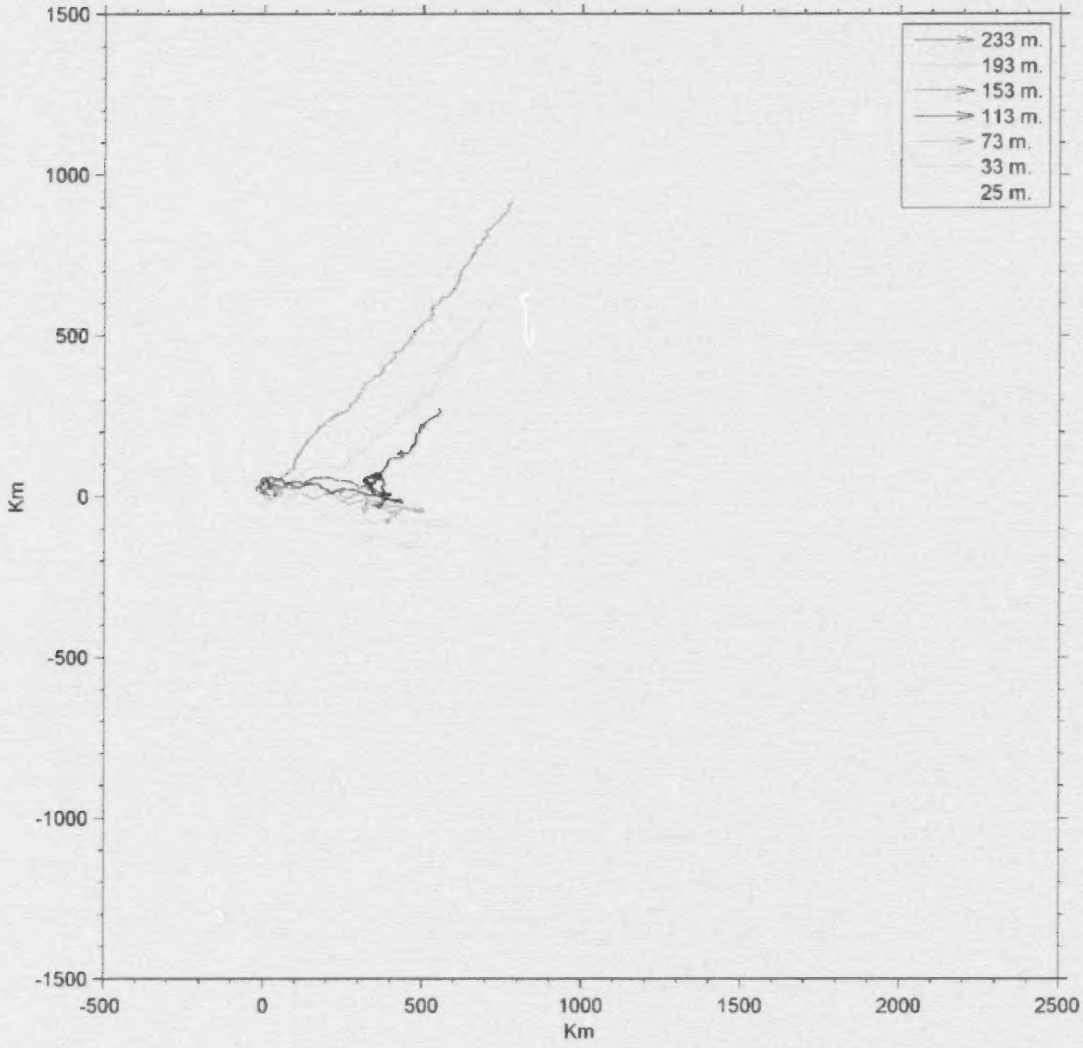


Figure 9: Progressive Vector Diagram, South Central Barrow Strait. (Workhorse ADCP) Aug. 10, 2010 – Aug. 7, 2011

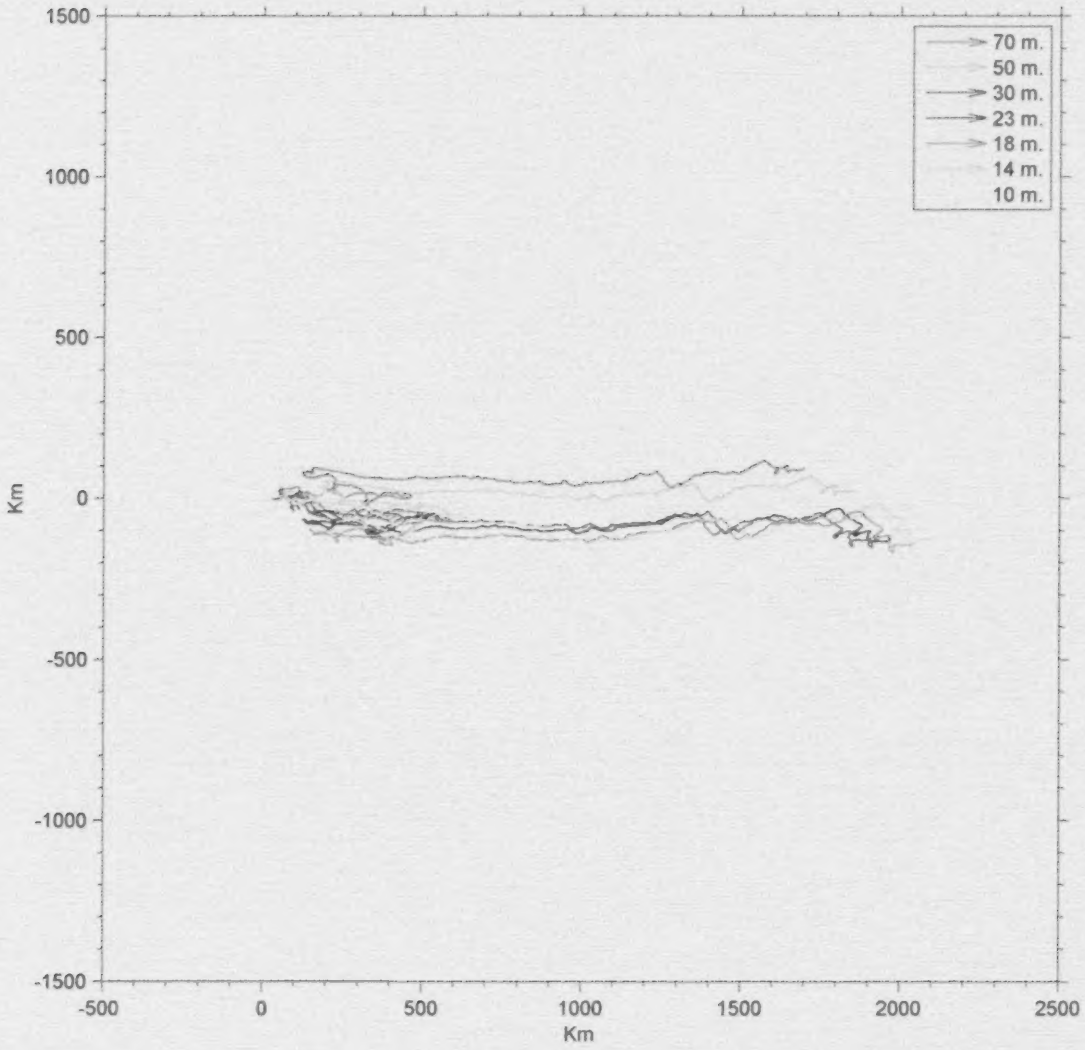
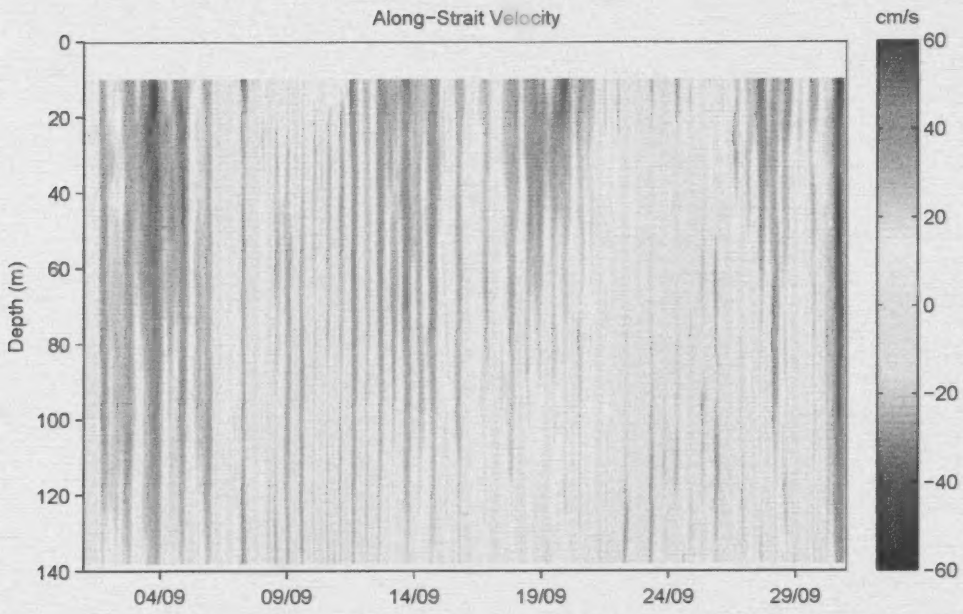


Figure 10: Bi-hourly current data, South Side Barrow Strait. Sep. 1, 2010 – Sep. 30, 2010



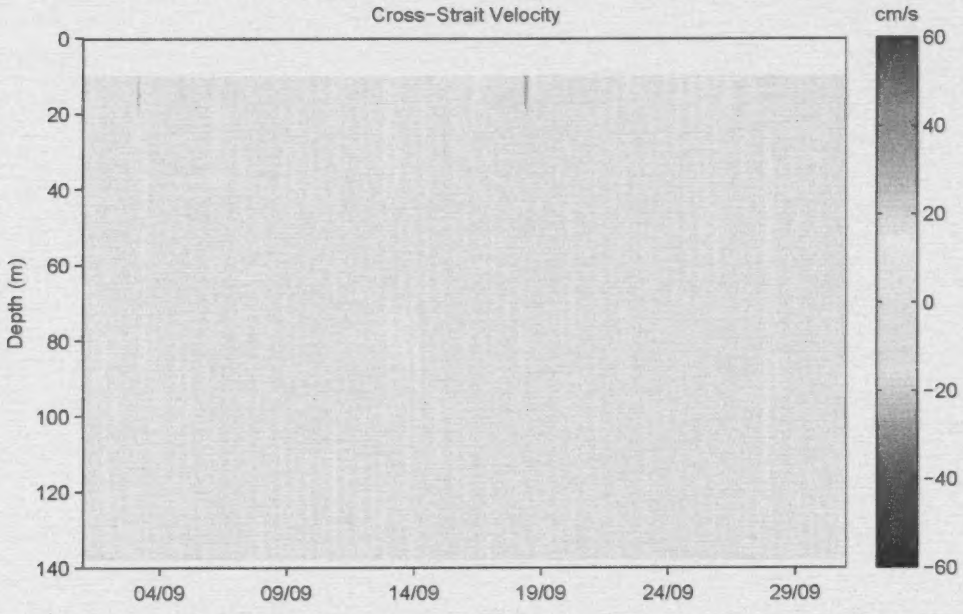


Figure 11: Bi-hourly current data, South Central Barrow Strait. (Quarter Master ADCP), Sep. 1, 2010 – Sep. 30, 2010

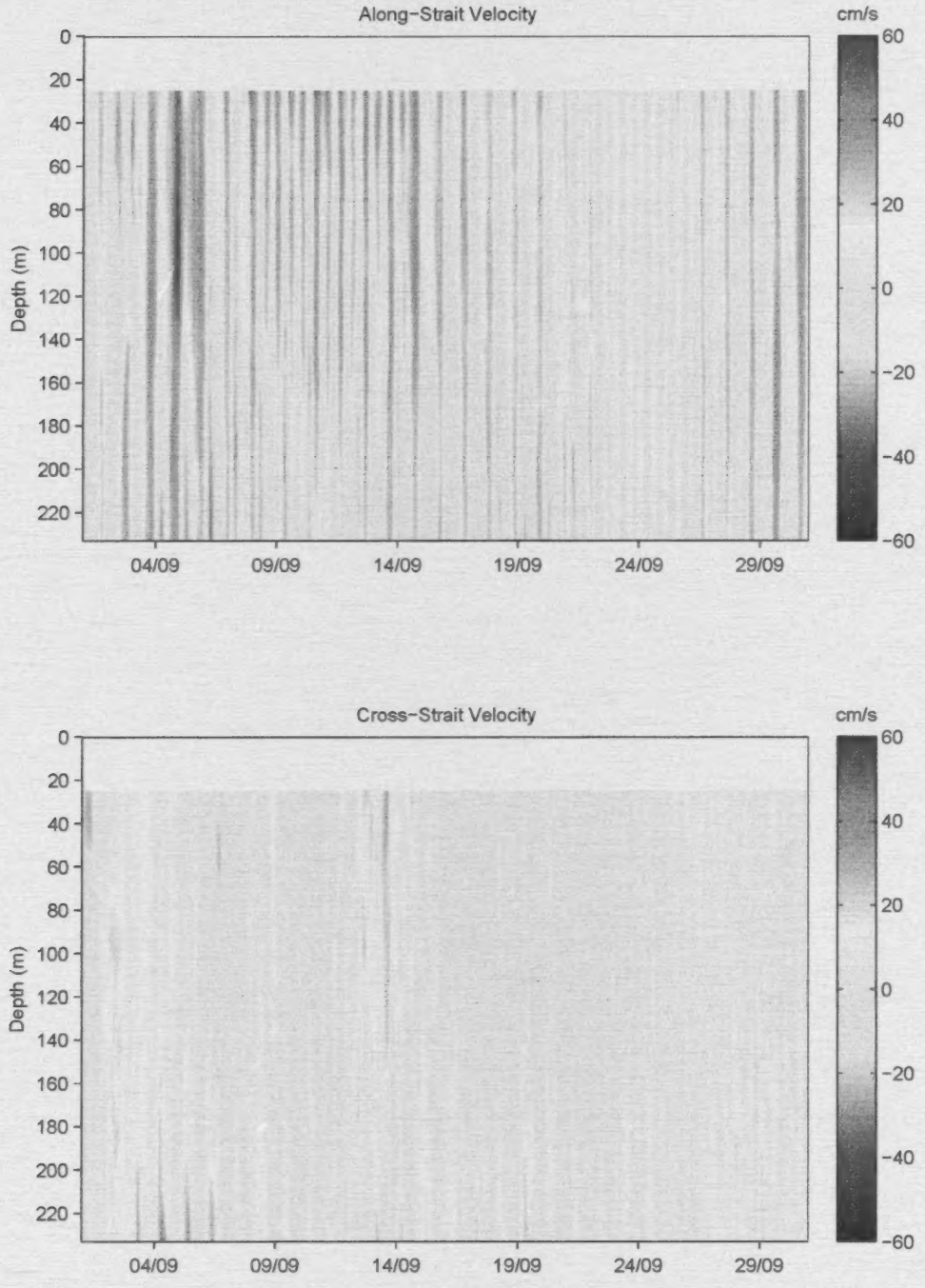
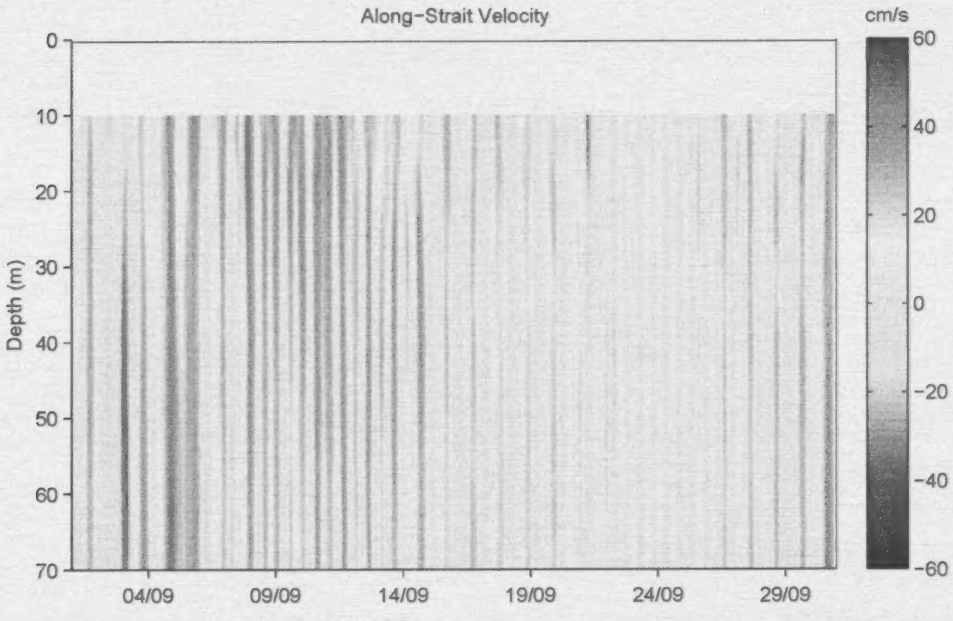


Figure 12: Bi-hourly current data, South Central Barrow Strait. (Workhorse ADCP) Sep. 1, 2010 – Sep. 30, 2010



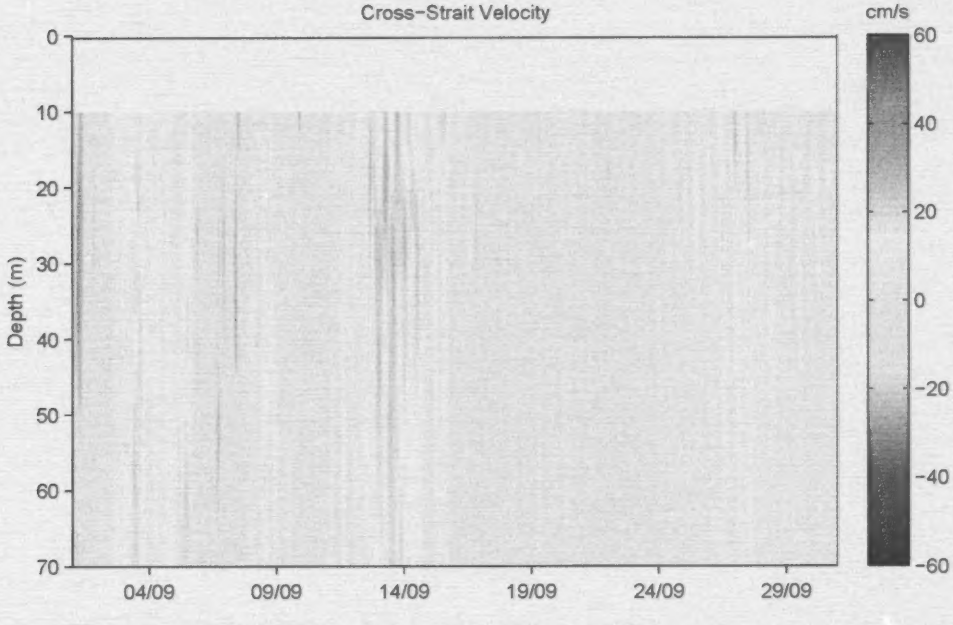
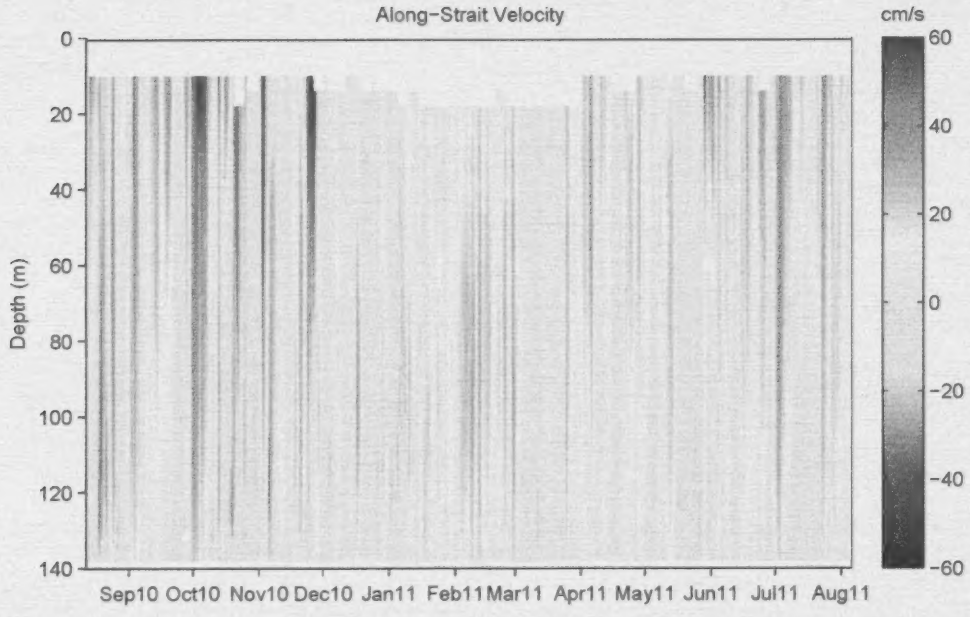


Figure 13: Low-pass filtered currents, South Side Barrow Strait. August 2010 – August 2011



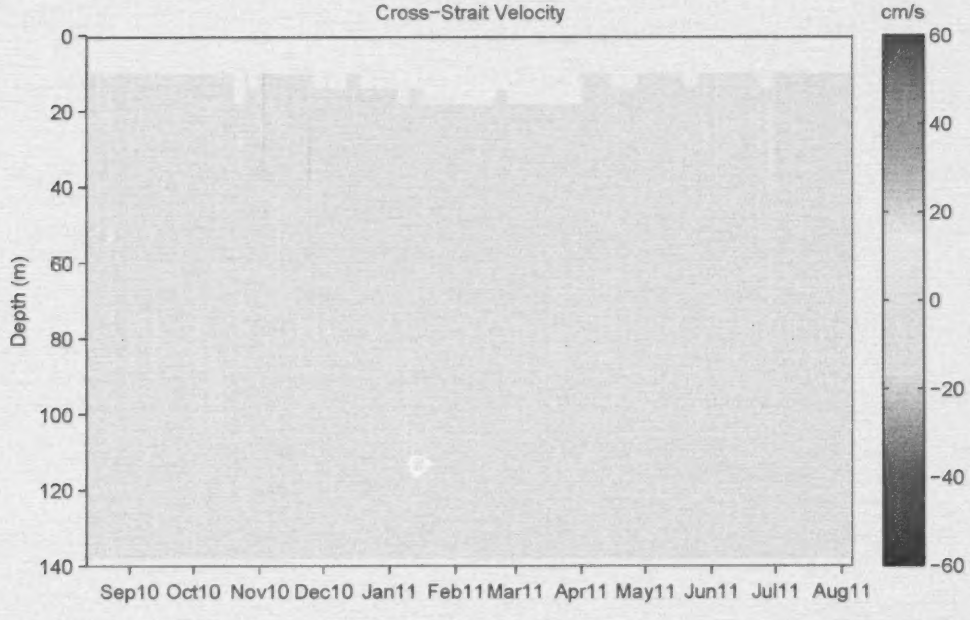
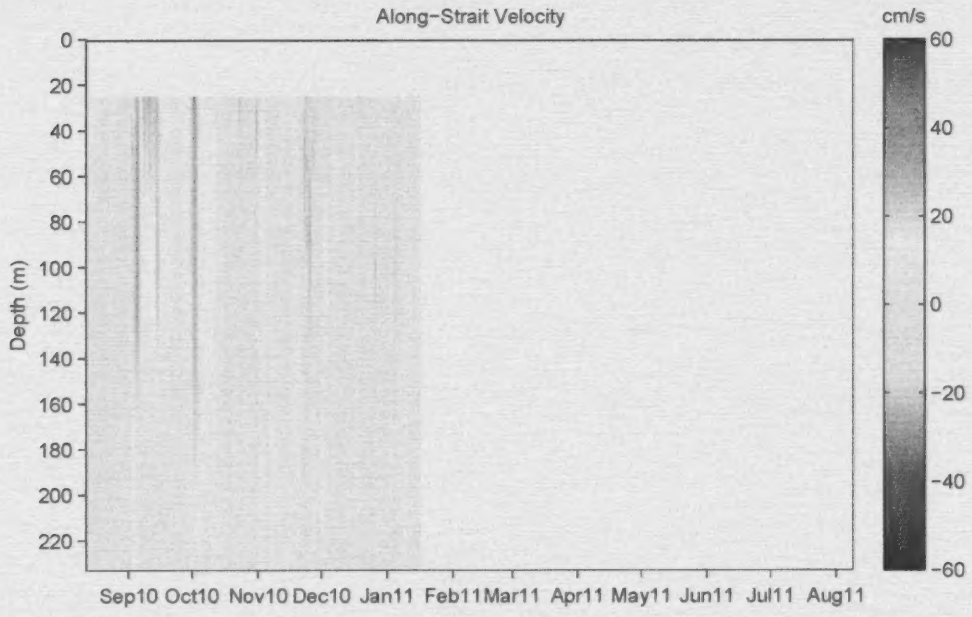


Figure 14: Low-pass filtered currents, South Central Barrow Strait. (Quarter Master ADCP) August 2010 – January 2011



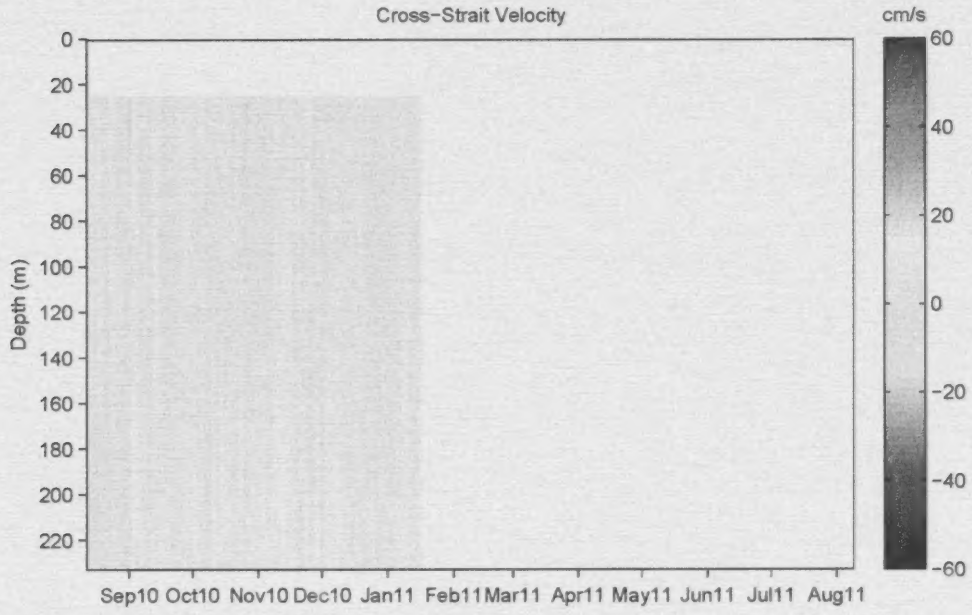
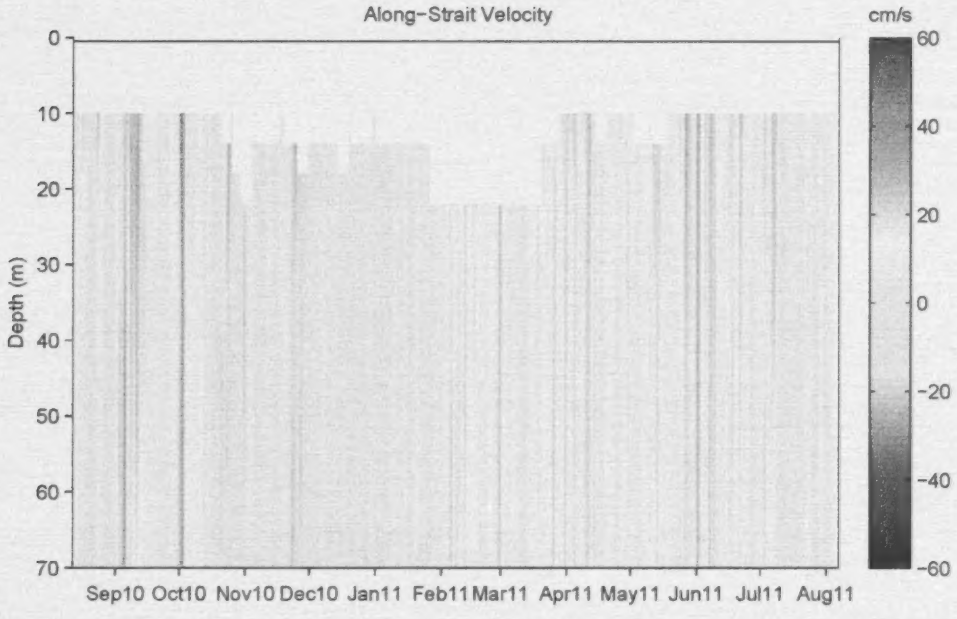


Figure 15: Low-pass filtered currents, South Central Barrow Strait. (Workhorse ADCP) August 2010 – August 2011



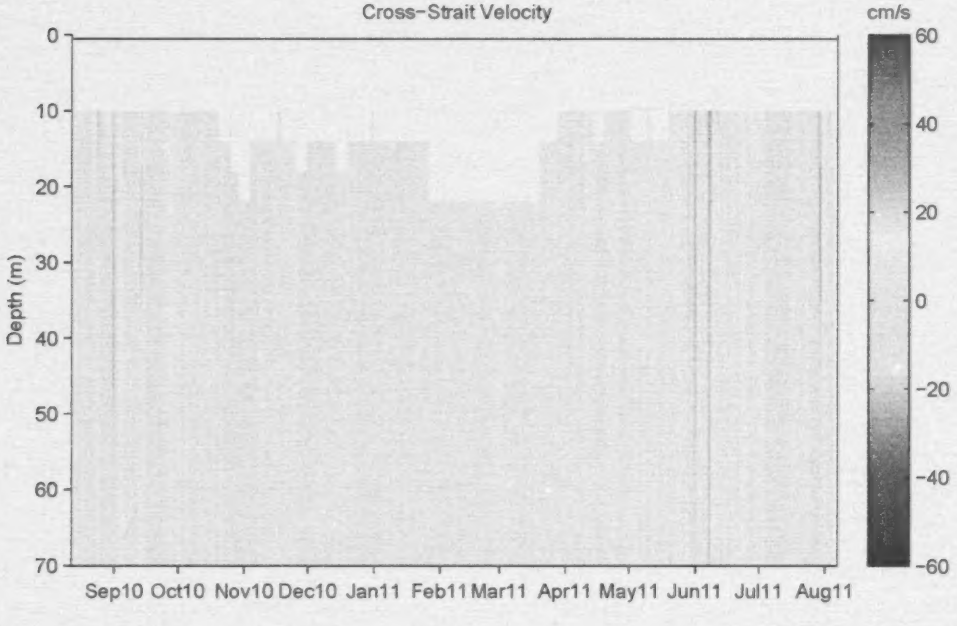


Figure 16: Low-pass filtered T,S (40 m.) and current data (35 m.). South Side Barrow Strait: August 2010 - August 2011.

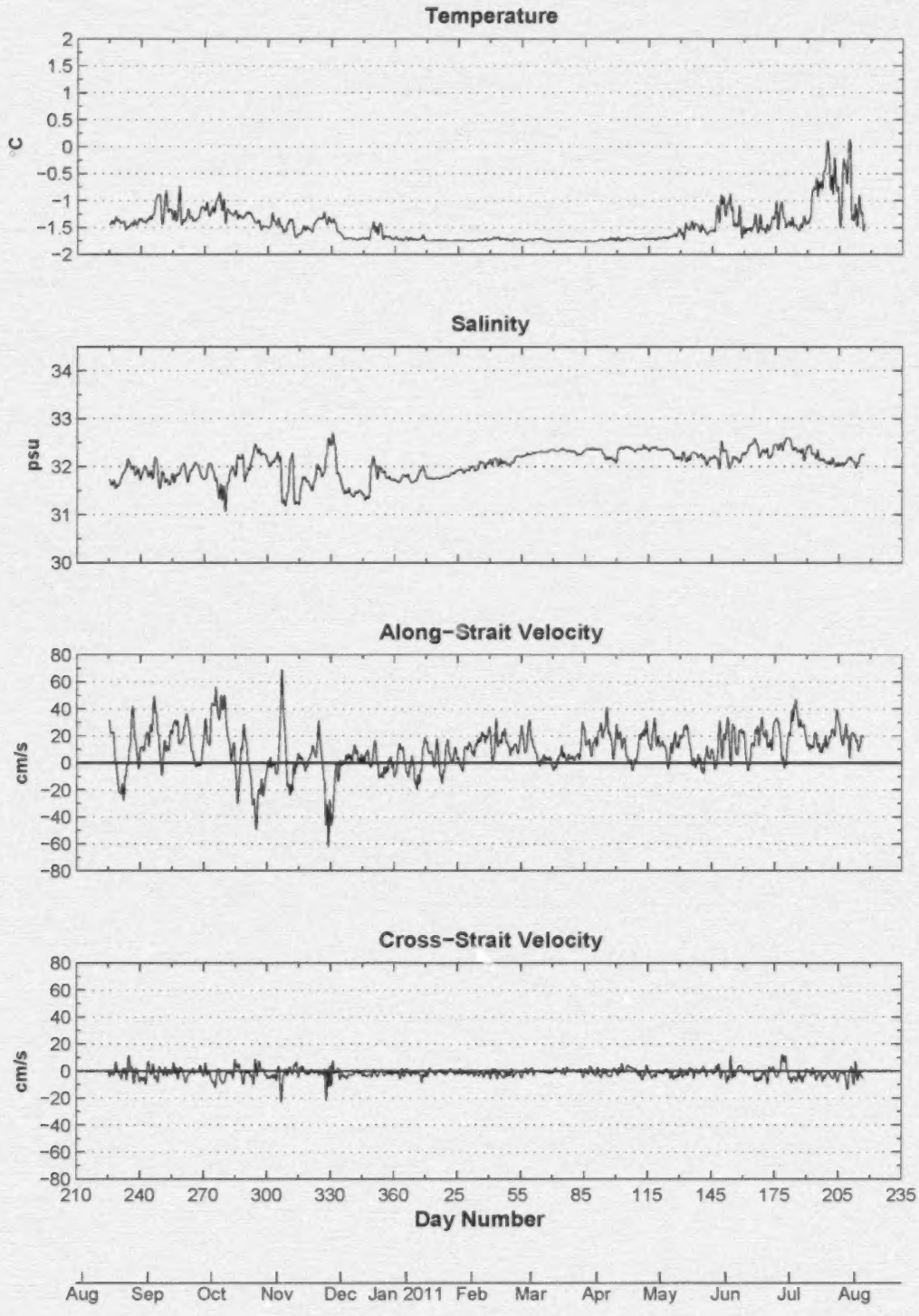


Figure 17: Low-pass filtered T,S (79 m.) and current data (78 m.). South Side Barrow Strait: August 2010 – August 2011.

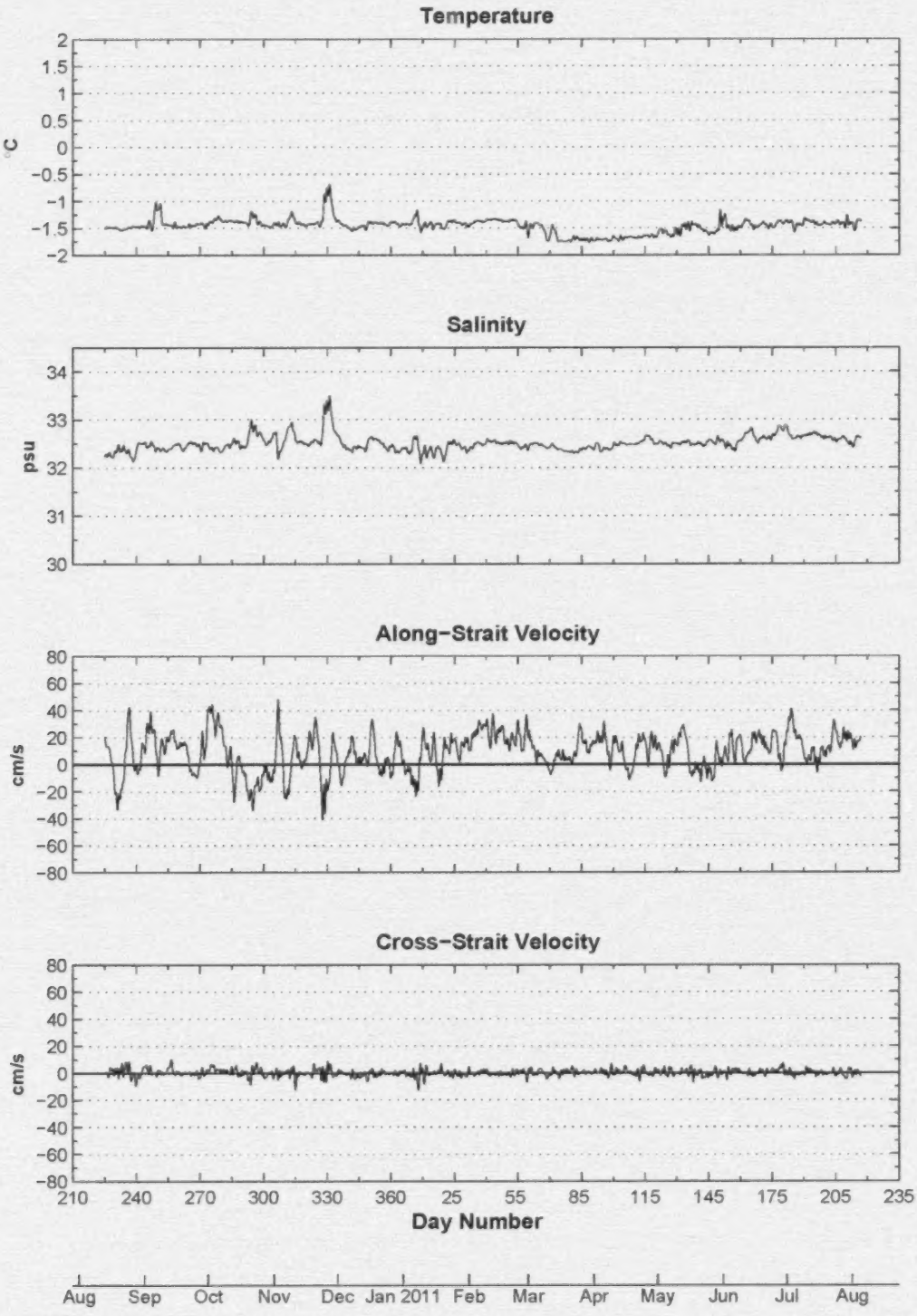


Figure 18: Low-pass filtered T,S (146 m.) and current data (138 m.). South Side Barrow Strait: August 2010 – August 2011.

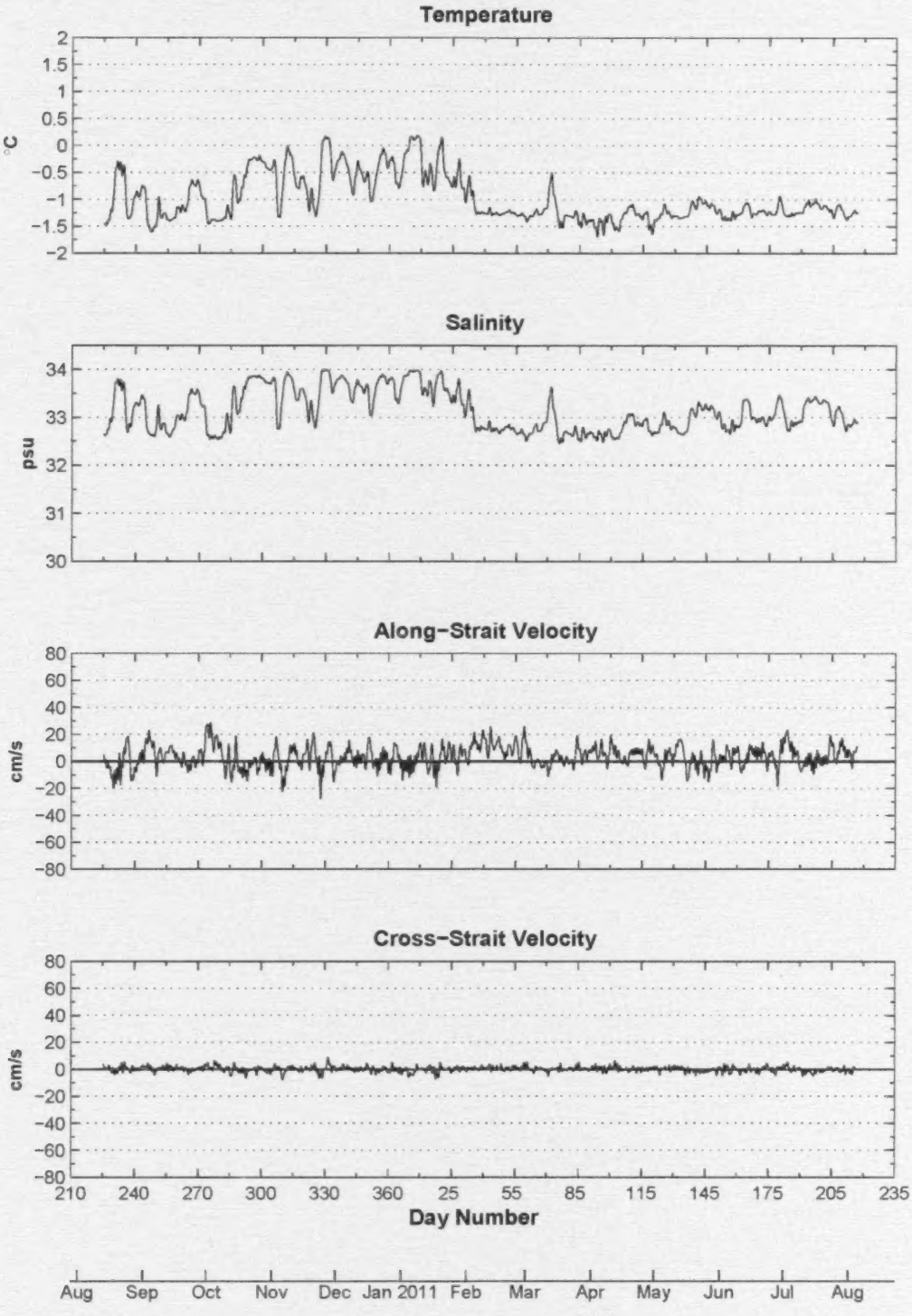


Figure 19: Low-pass filtered T,S data (39 m.) and current data (38 m.) South Central Barrow Strait: August 2010 – August 2011.

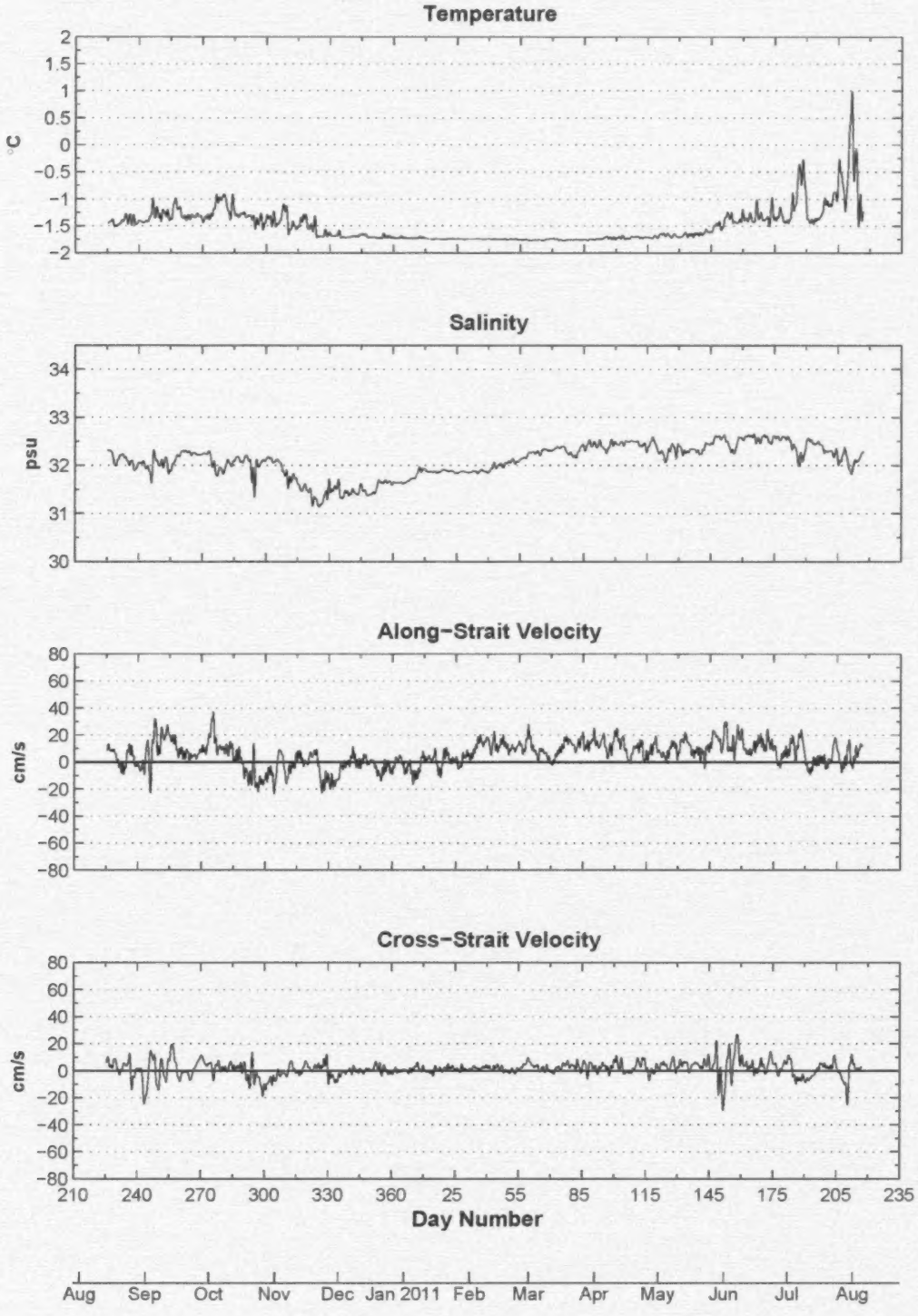


Figure 20: Low-pass filtered T,S data (56 m.) and current data (54 m.) South Central Barrow Strait: August 2010 – August 2011.

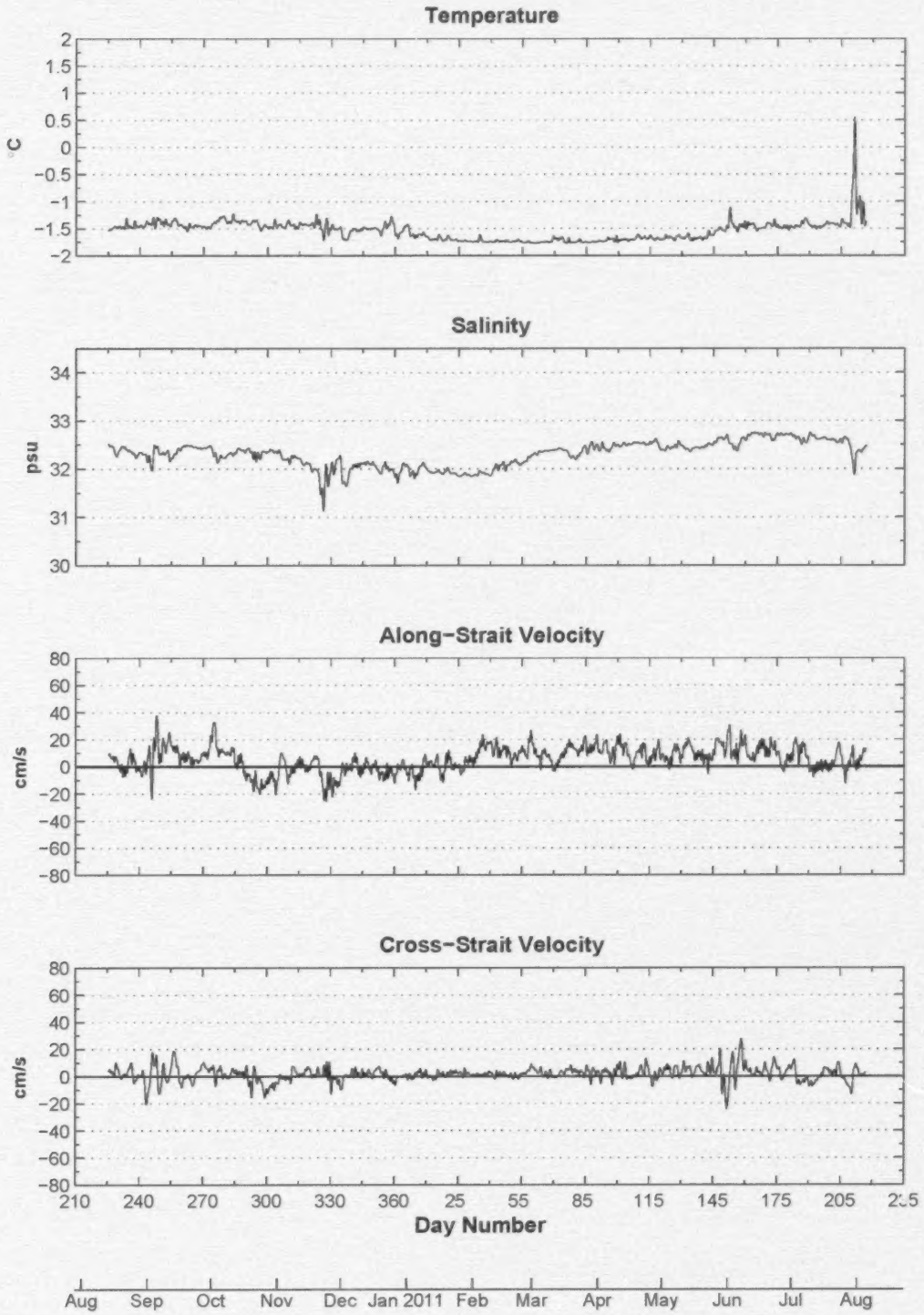


Figure 21: Low-pass filtered T,S (154 m.) and current data (153 m.). South Central Barrow Strait: August 2010 - August 2011.

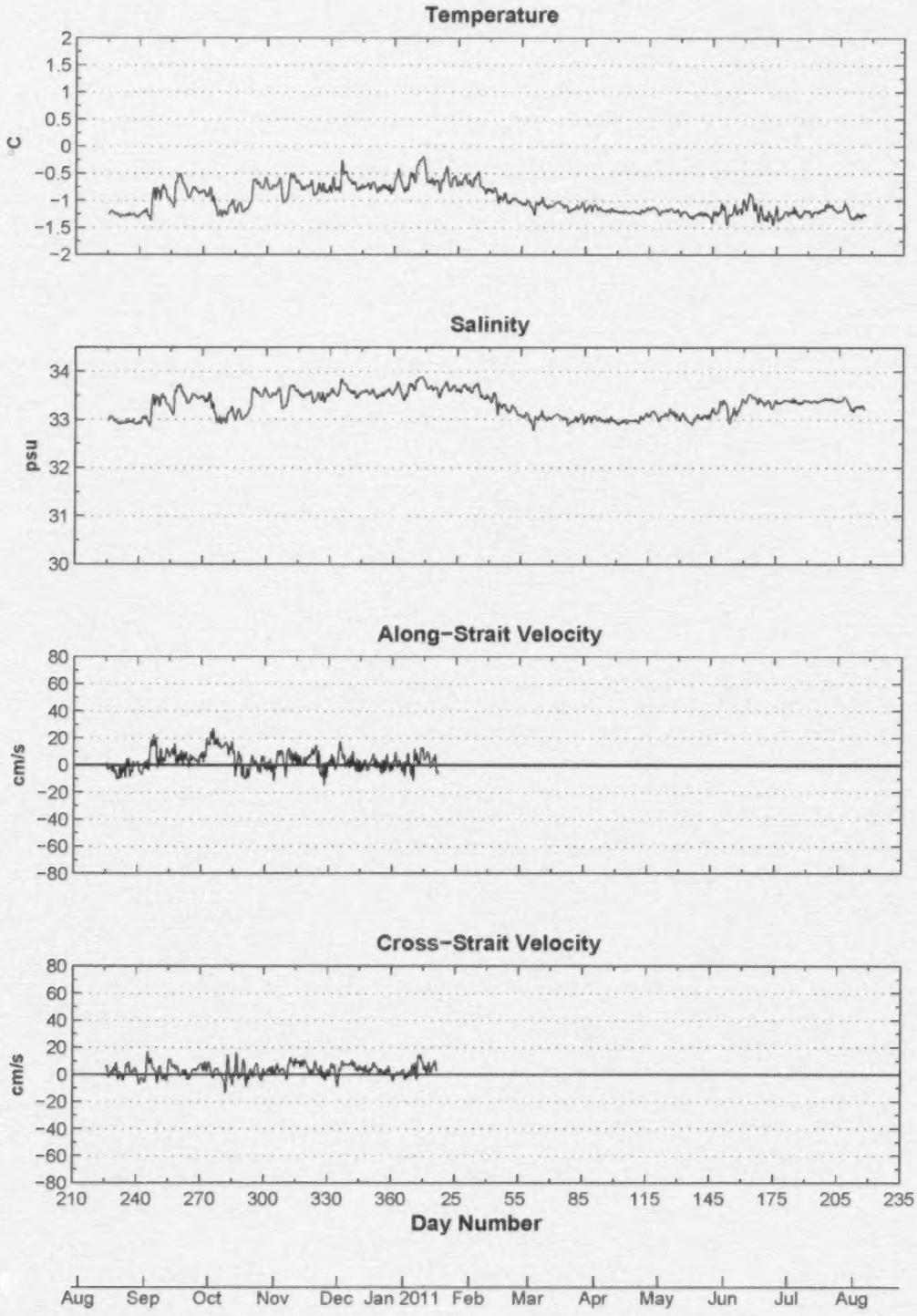


Figure 22: Low-pass filtered T,S (264 m) and current data (233 m.). South Central Barrow Strait: August 2010 - August 2011.

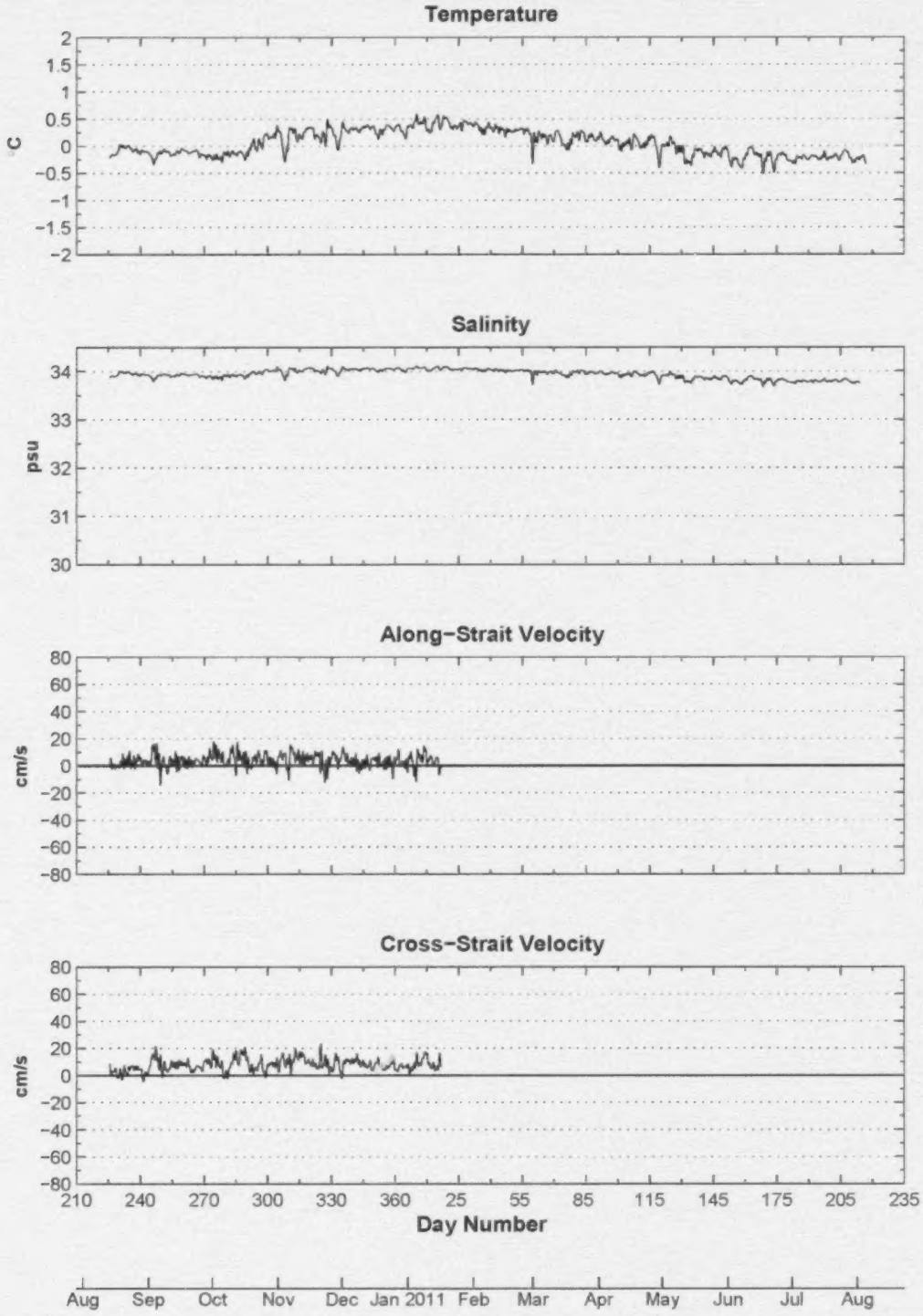
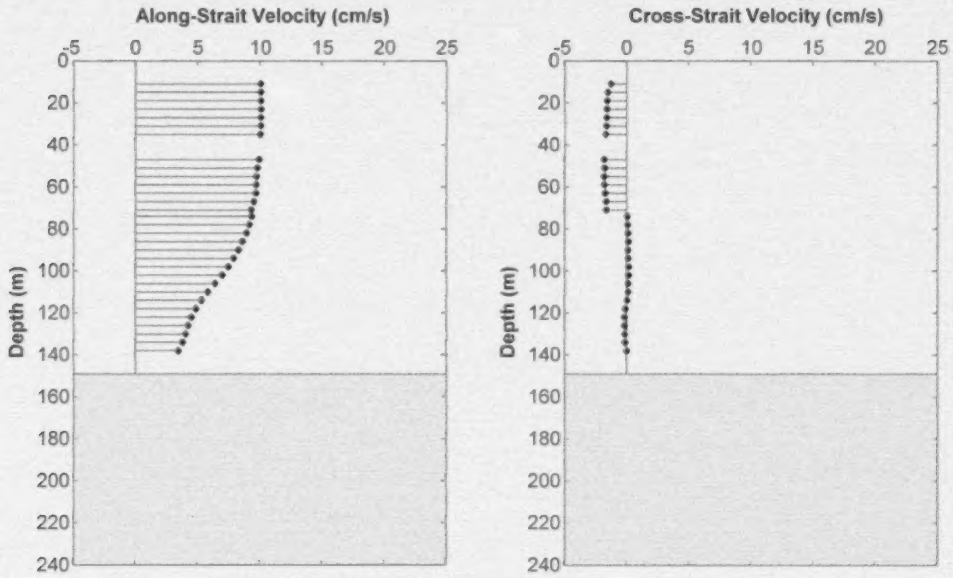


Figure 23: Mean Flows, August 2010 to August 2011.

South side of Barrow Strait



South Central Barrow Strait (WHADCP)

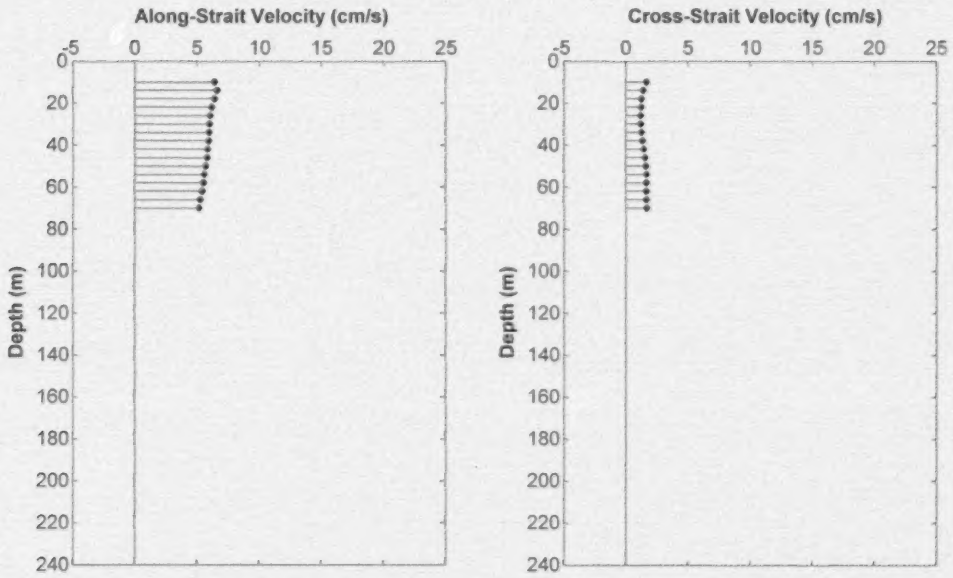


Figure 23: Mean Flows, August 2010 to January 2011. (continued)

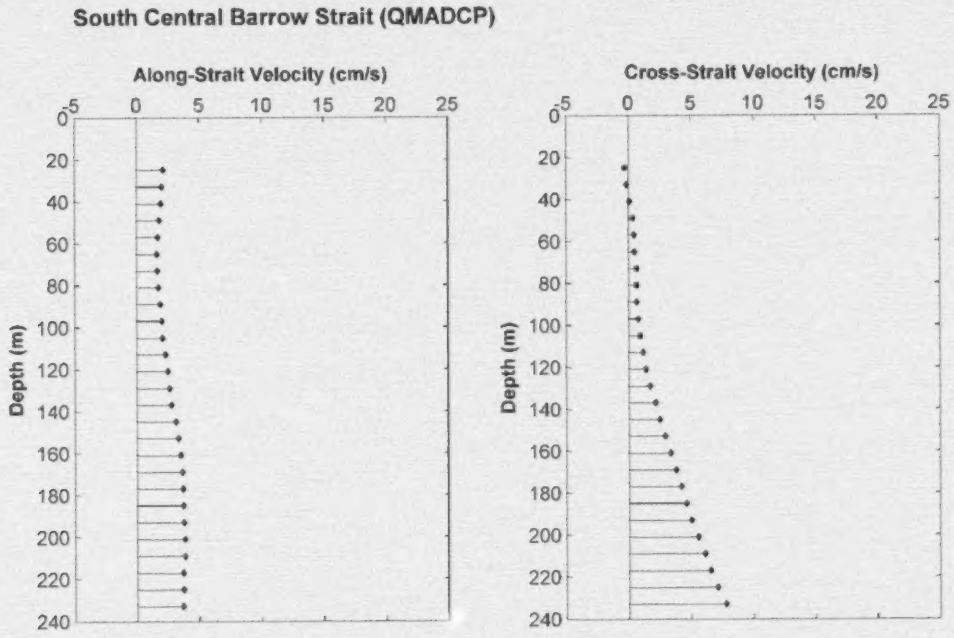
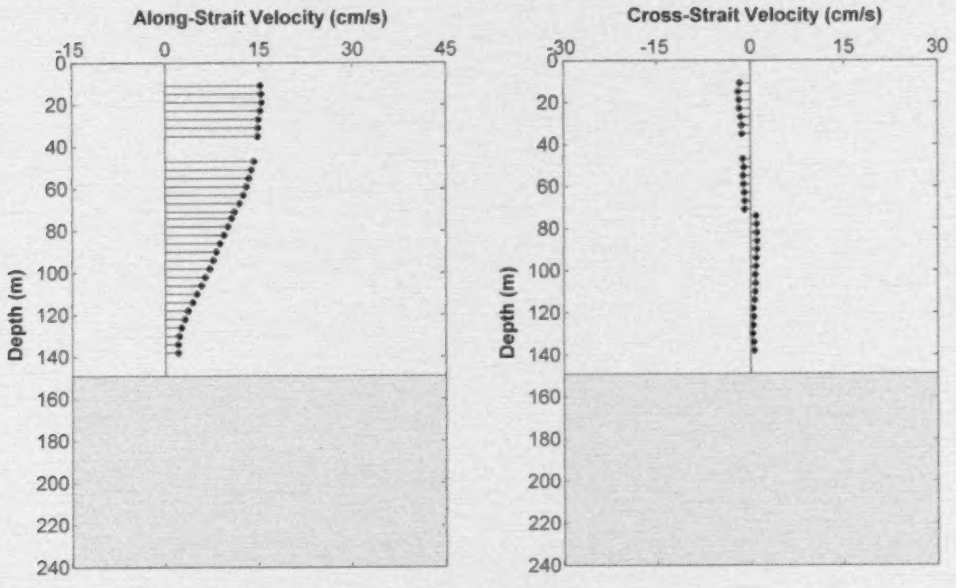


Figure 24: Mean Flows, Late Summer: Aug. 2010 to Sep. 2010.

South side of Barrow Strait



South Central Barrow Strait (WHADCP)

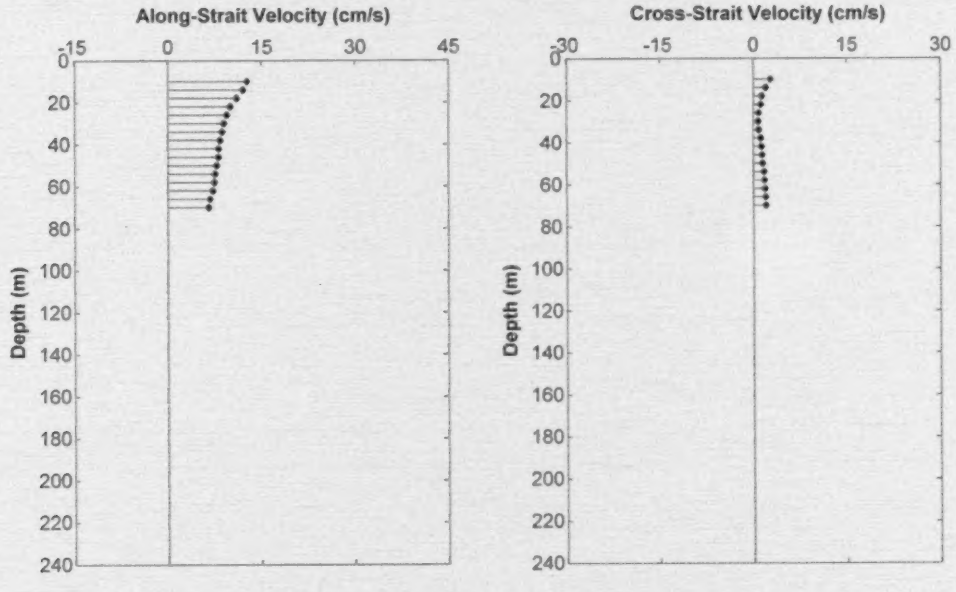


Figure 24: Mean Flows, Late Summer: Aug. 2010 to Sep. 2010 (continued)

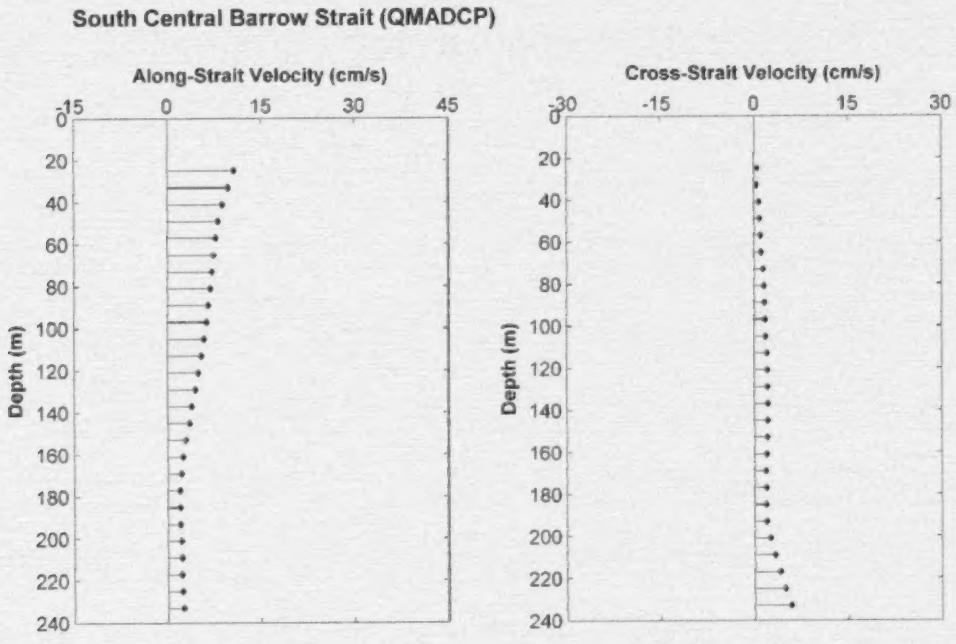


Figure 25: Mean Flows, Fall: Sep. 2010 to Dec. 2010.

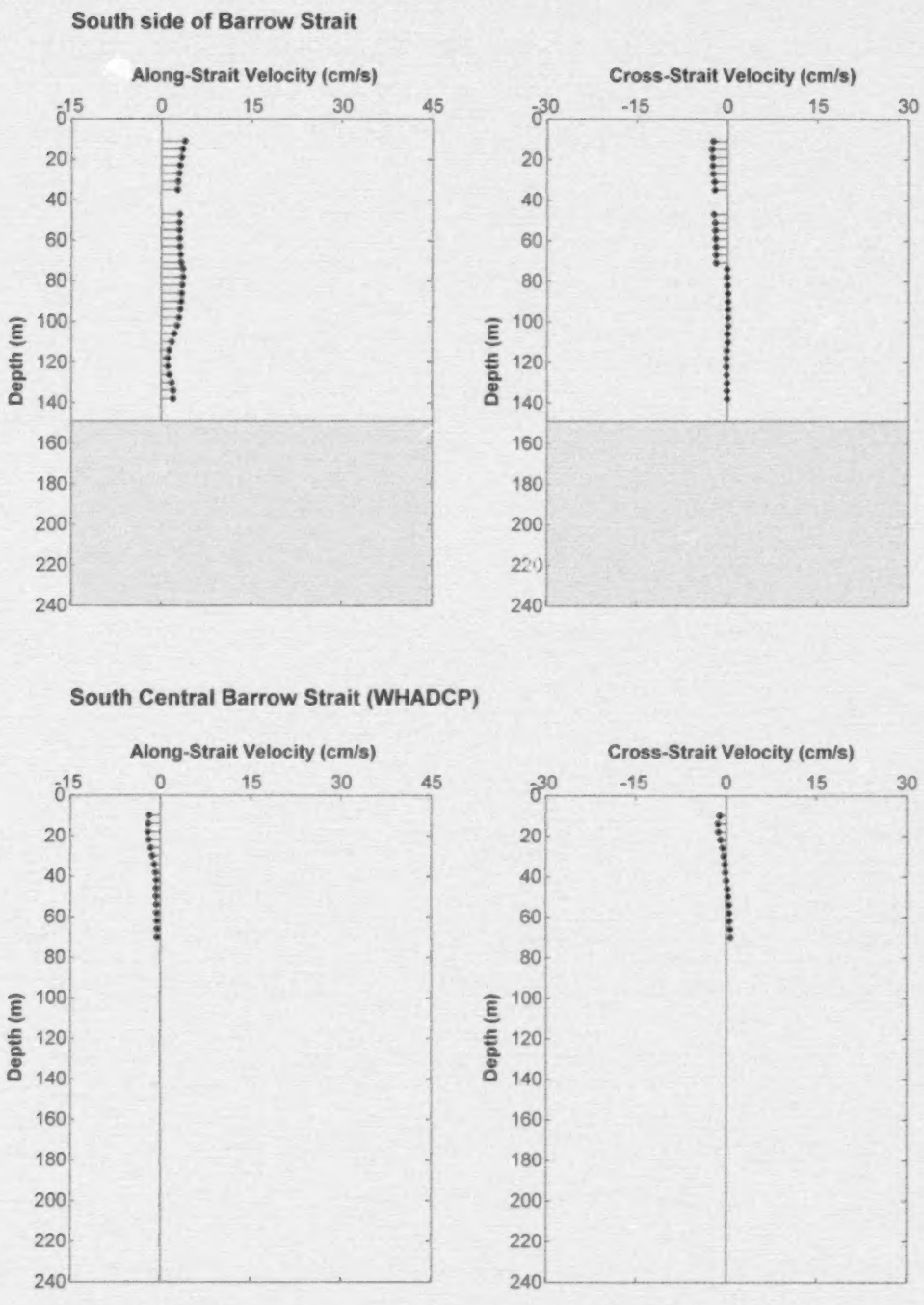


Figure 25: Mean Flows, Fall: Sep. 2010 to Dec. 2010 (continued).

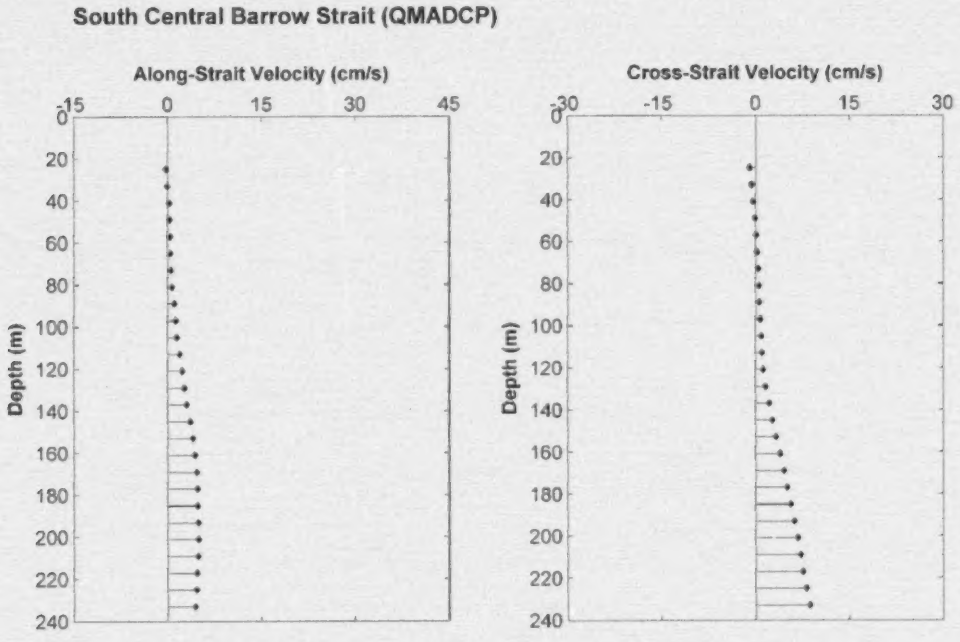


Figure 26: Mean Flows, Winter: Dec. 2010 to Mar. 2011.

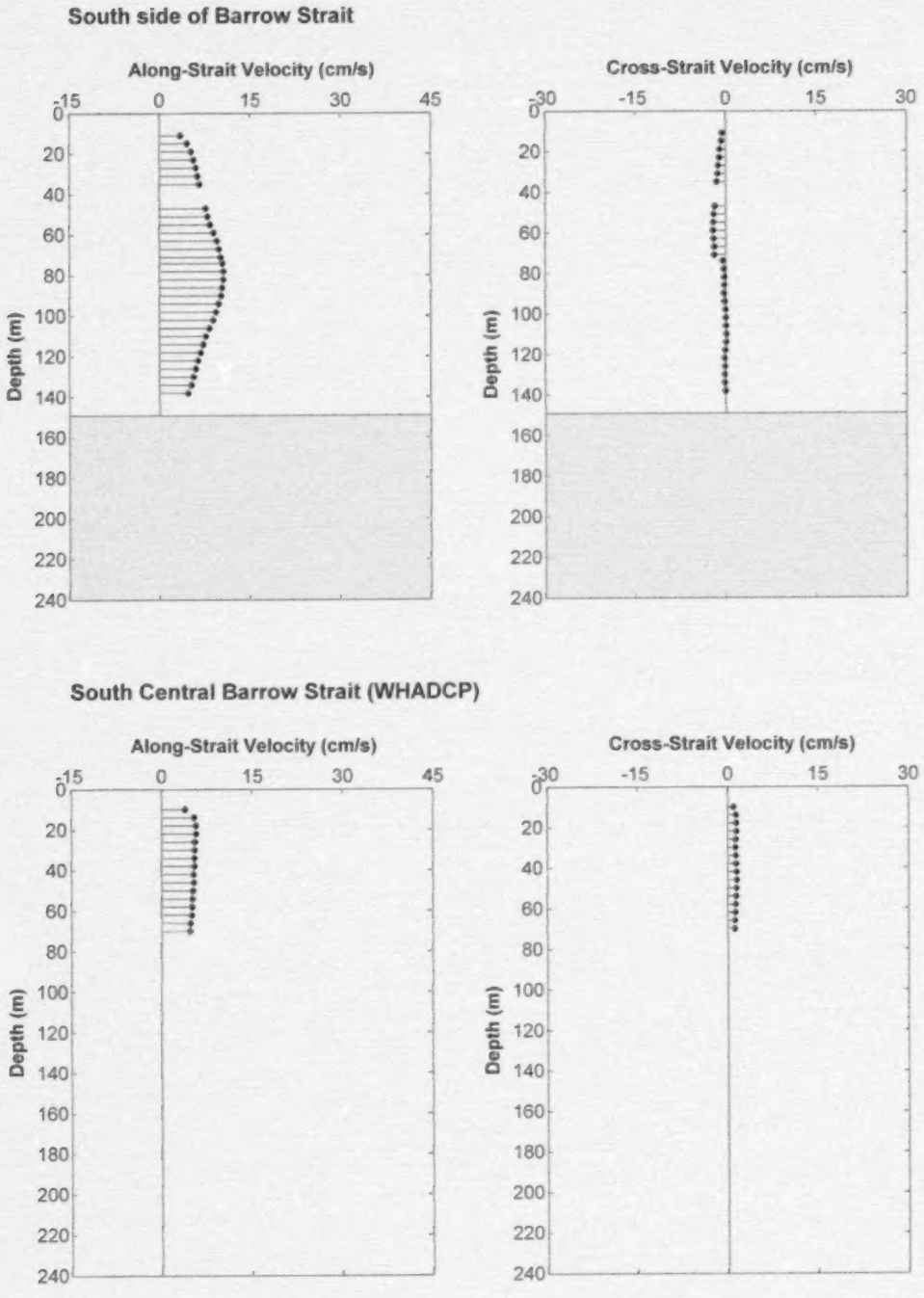


Figure 26: Mean Flows, Winter: Dec. 2010 to Jan. 2011 (continued).

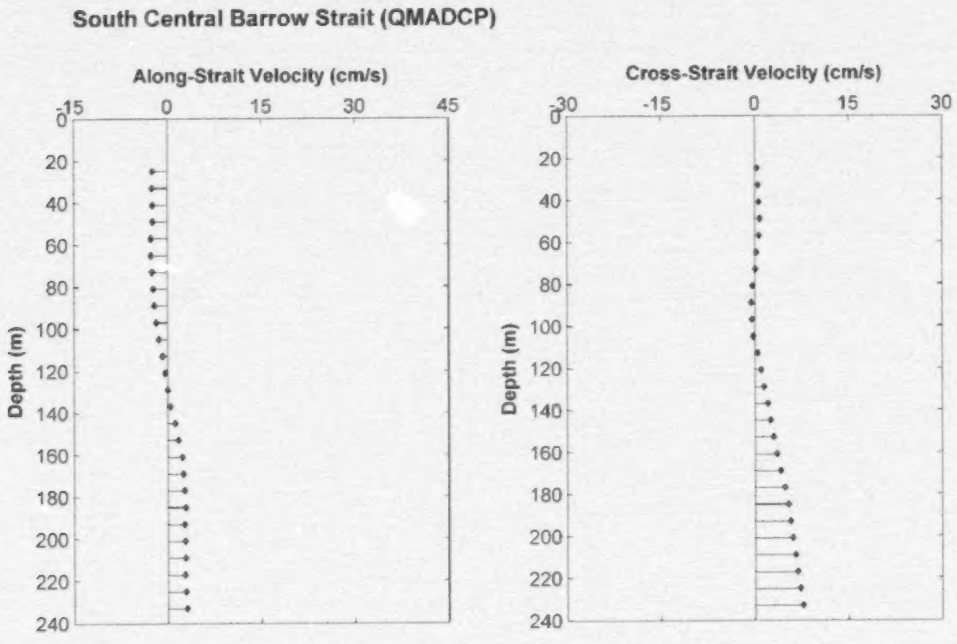
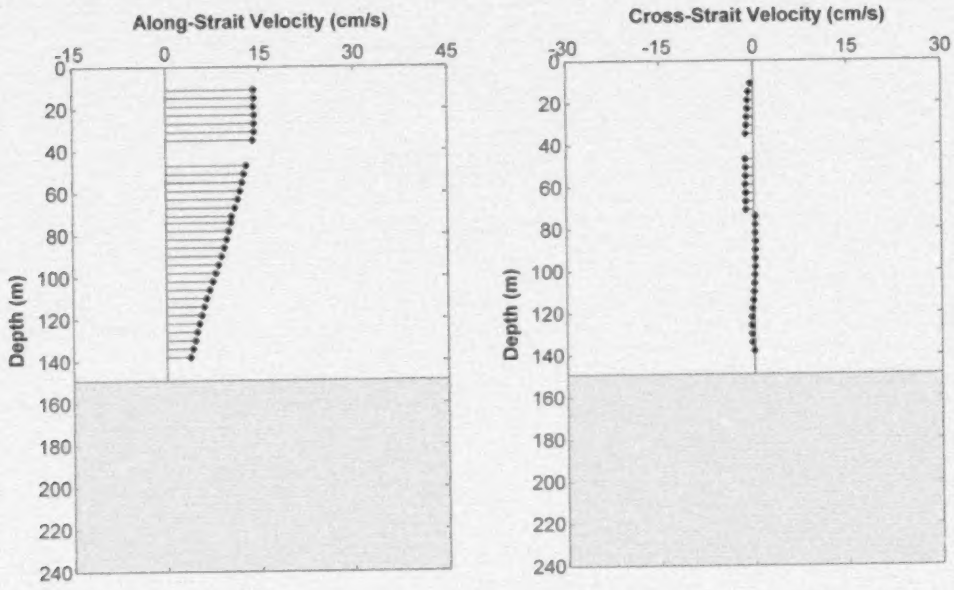


Figure 27: Mean Flows, Spring: Mar. 2011 to Jun. 2011.

South side of Barrow Strait



South Central Barrow Strait (WHADCP)

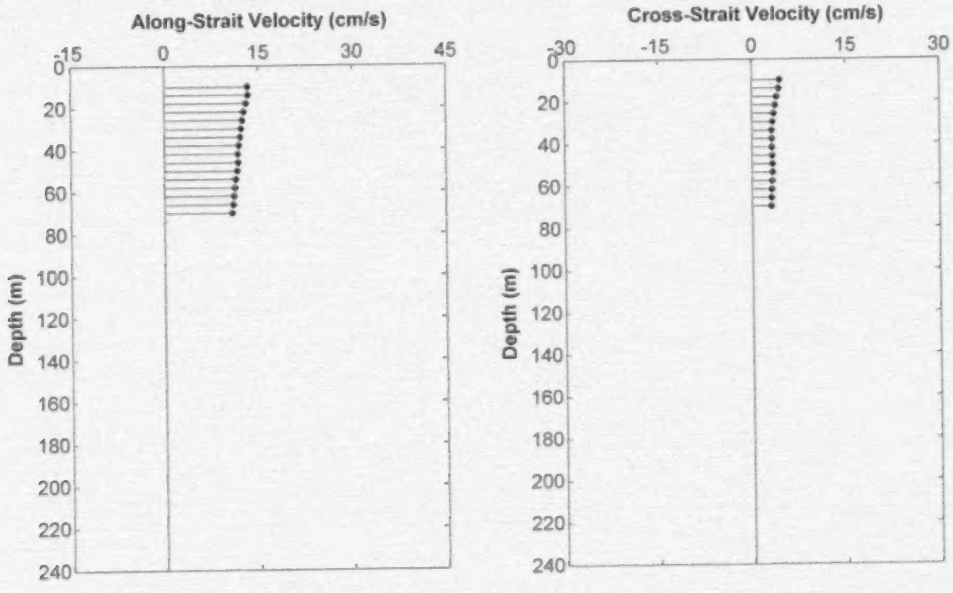


Figure 27: Mean Flows, Spring: Mar. 2011 to Jun. 2011 (continued).

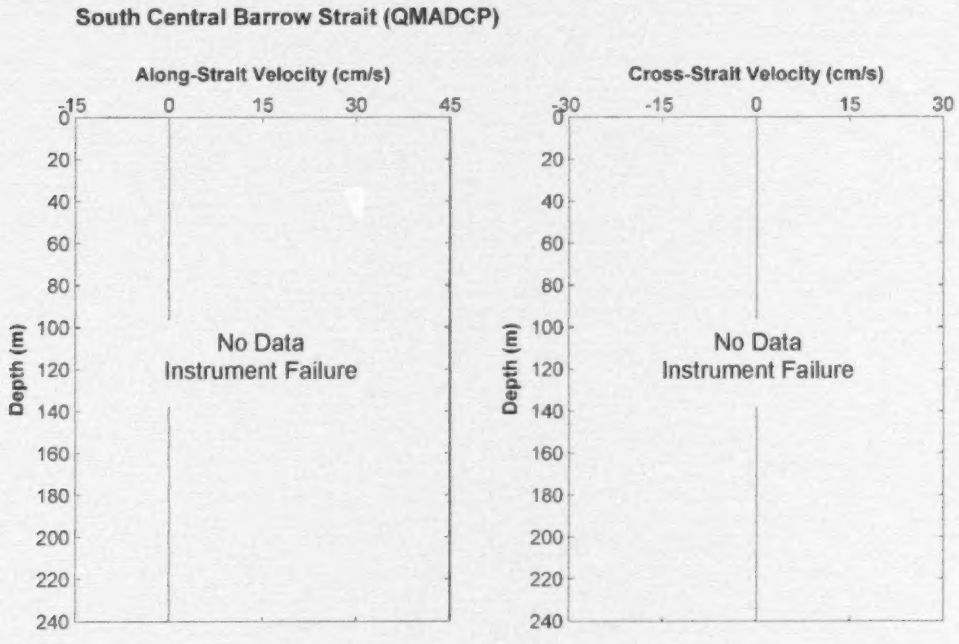


Figure 28: Mean Flows, Early Summer: Jun. 2011 to Aug. 2011.

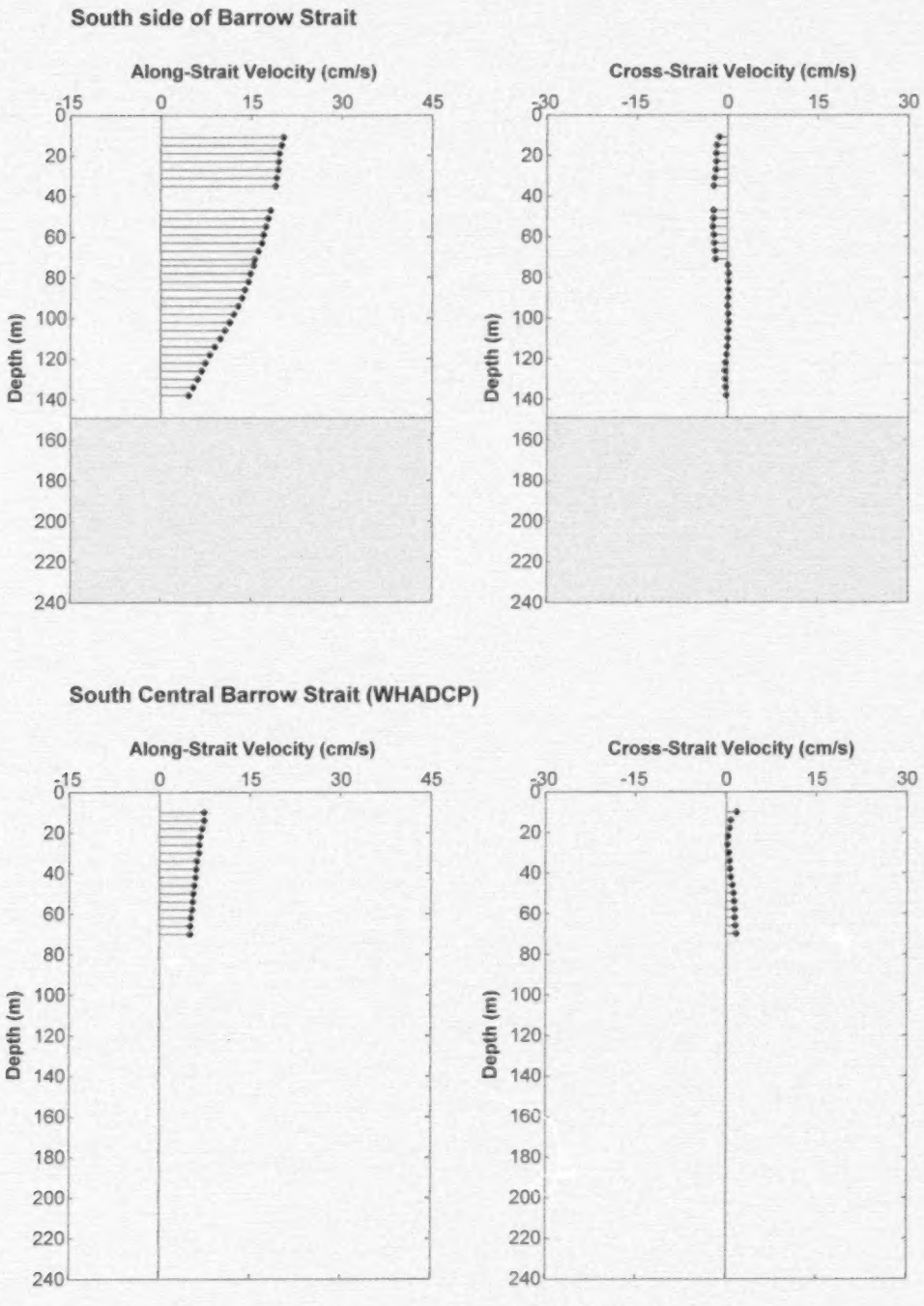


Figure 28: Mean Flows, Early Summer: Jun. 2011 to Aug. 2011 (continued).

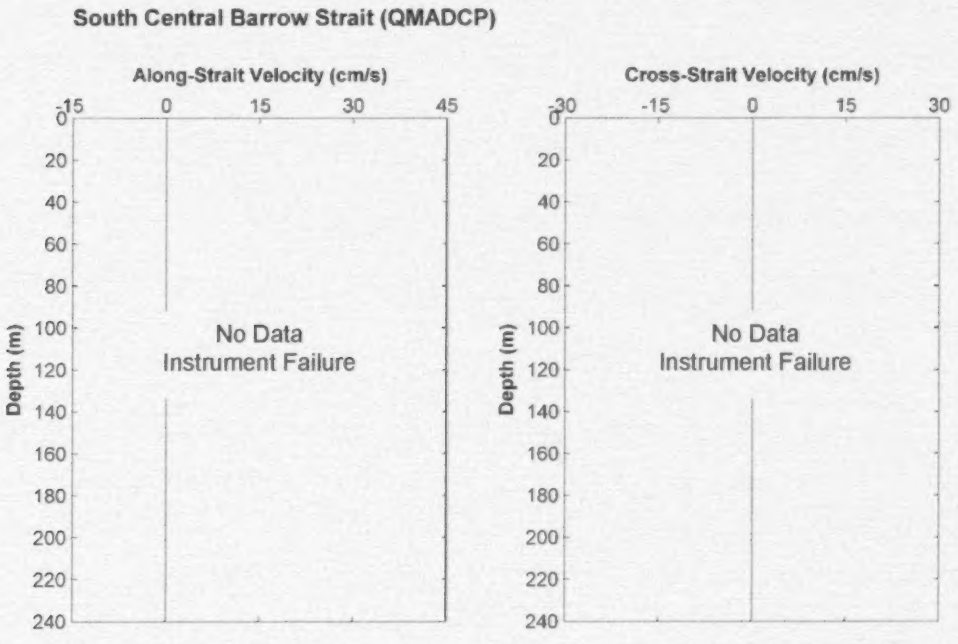


Figure 29: Variance in bi-hourly and low-pass filtered currents. Aug. 2010 to Aug. 2011.

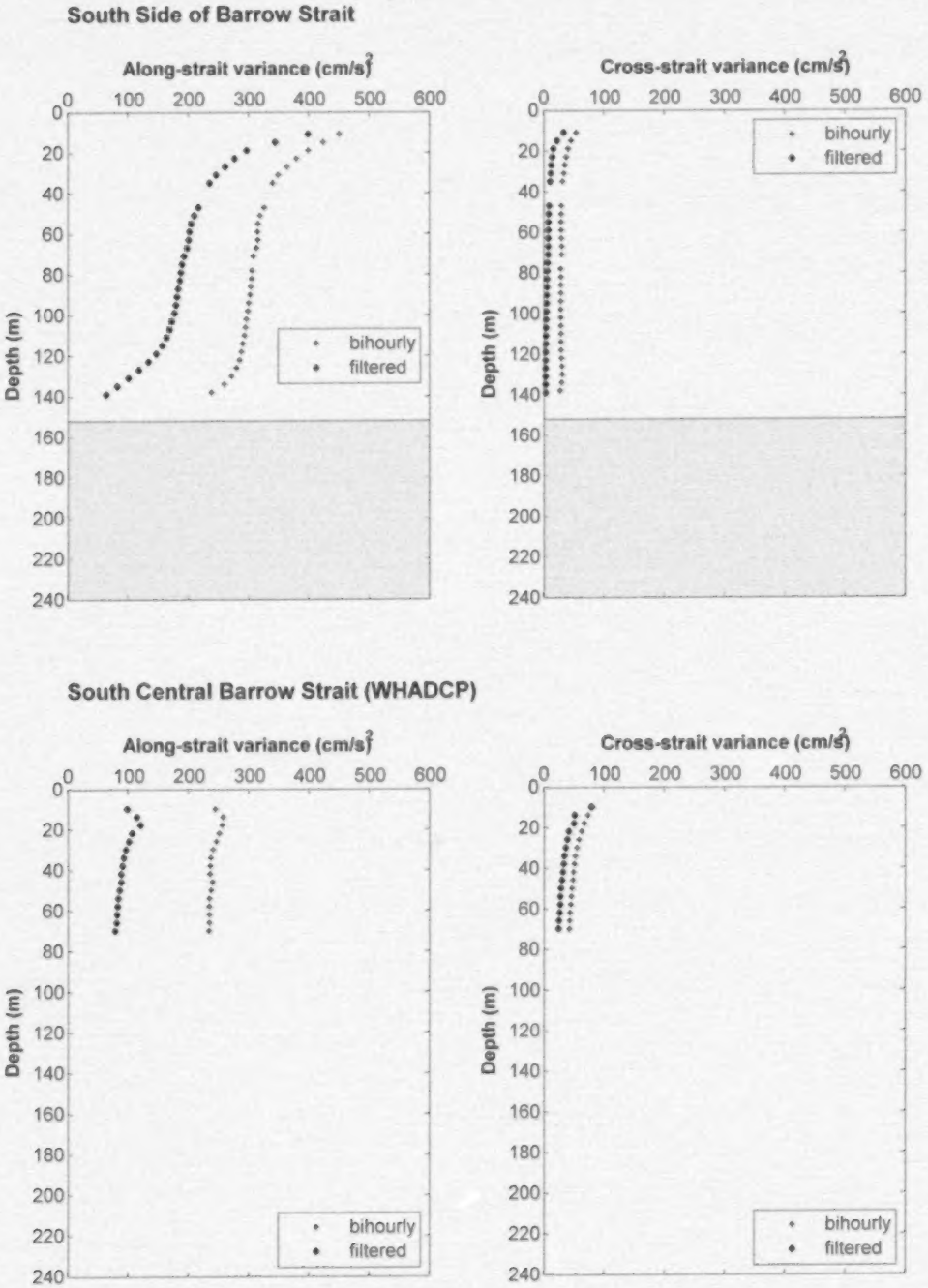


Figure 29: Variance in bi-hourly and low-pass filtered currents Aug. 2010 to Jan. 2011 (continued).

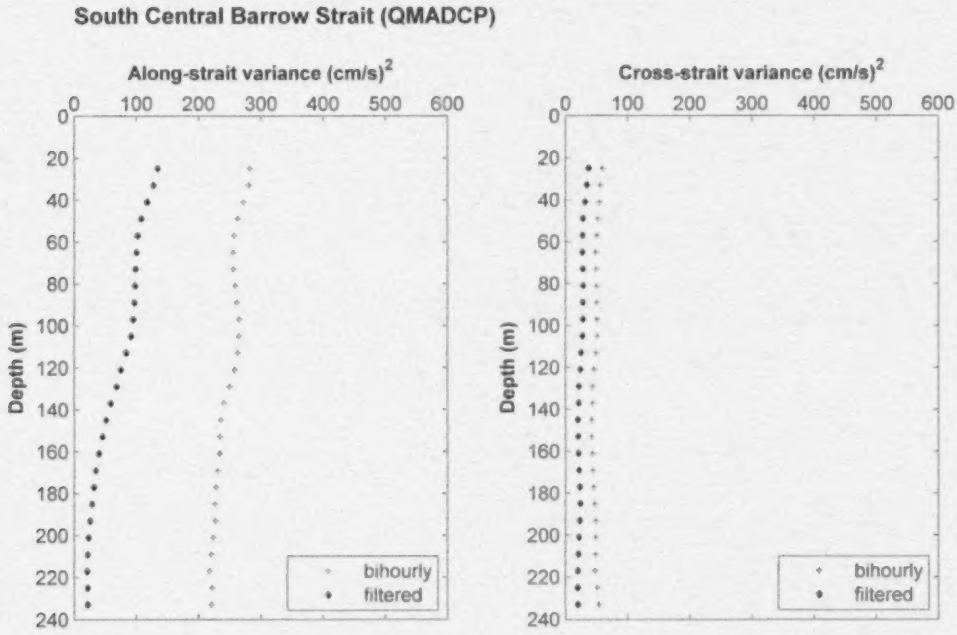
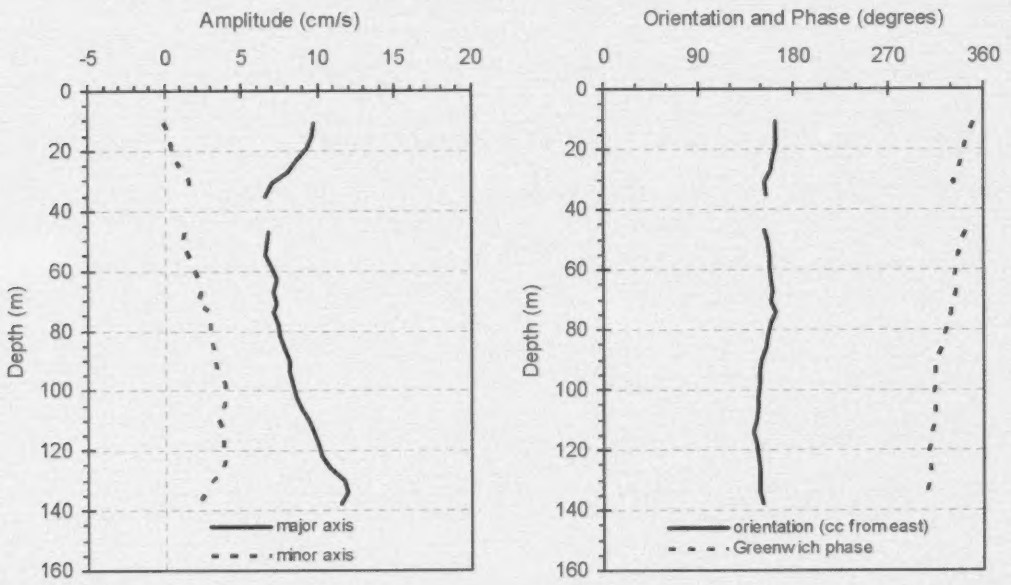


Figure 30: K1 Tidal Constituent, South Side of Barrow Strait

For Ice Free Period (Aug. 10, 2010 to Oct. 6, 2010):



For Solid Ice Period

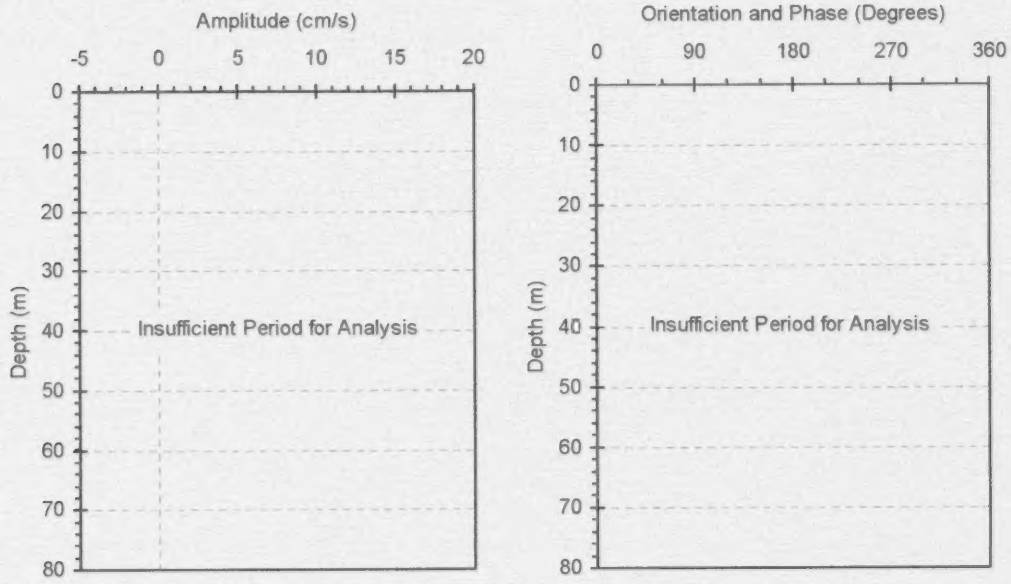
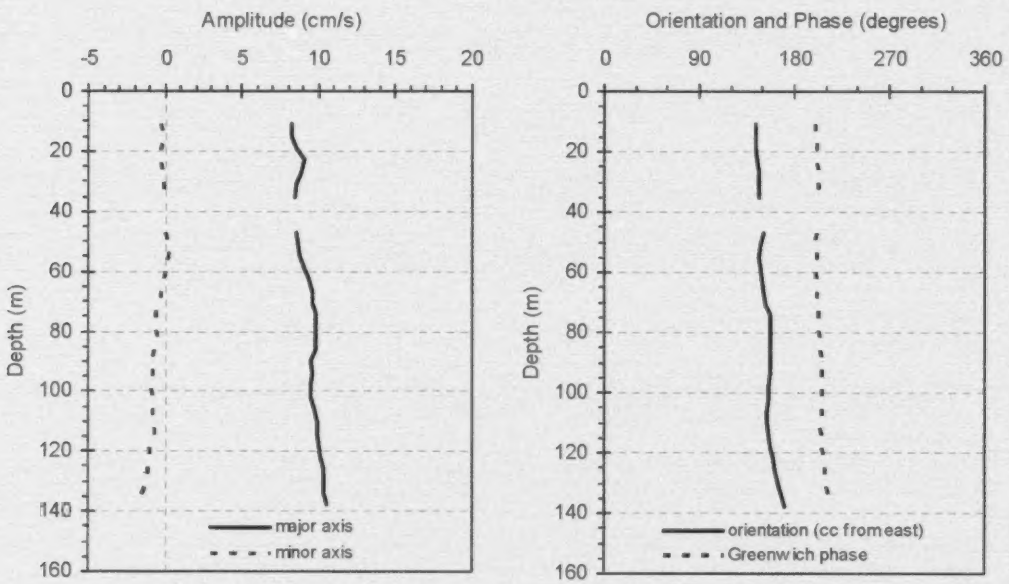


Figure 31: M2 Tidal Constituent, South Side of Barrow Strait

For Ice Free Period (Aug. 10, 2010 to Oct. 6, 2010):



For Solid Ice Period

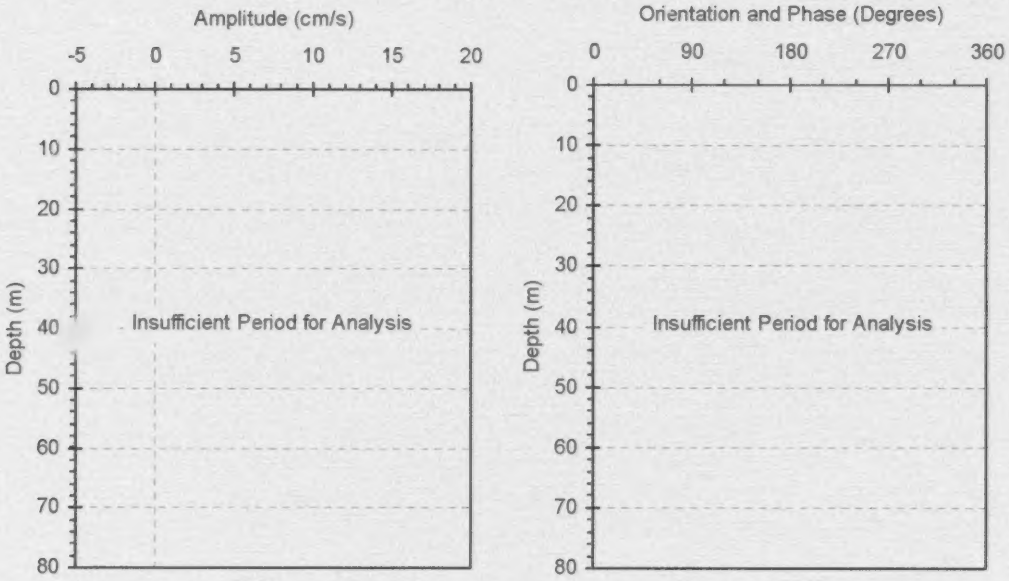
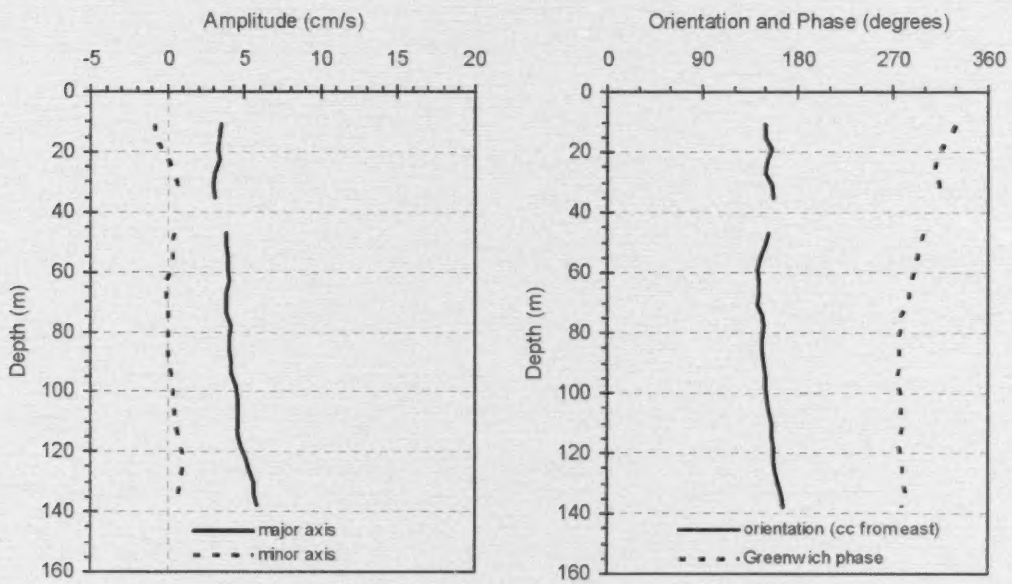


Figure 32: O1 Tidal Constituent, South Side of Barrow Strait

For Ice Free Period (Aug. 10, 2010 to Oct. 6, 2010):



For Solid Ice Period

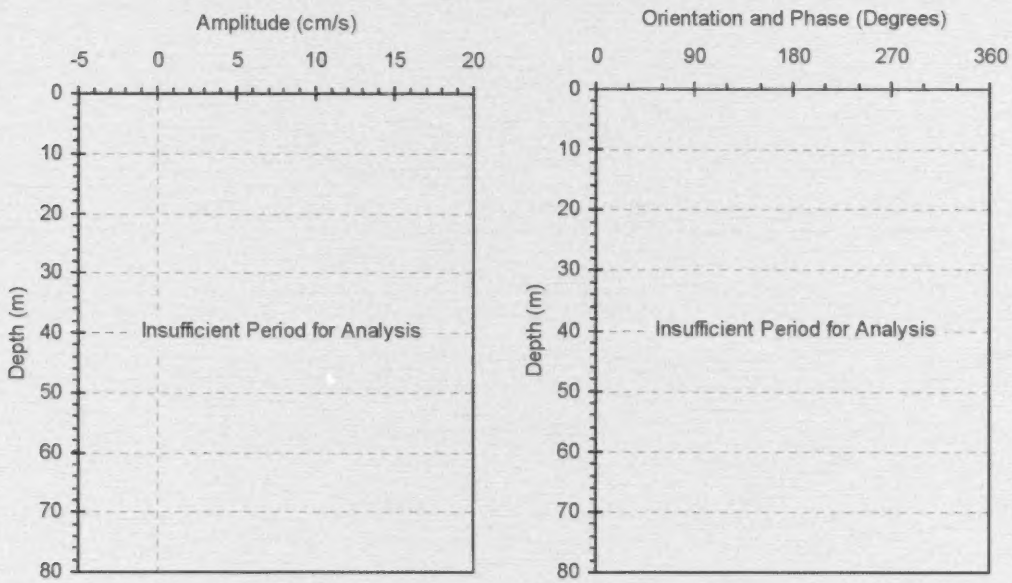
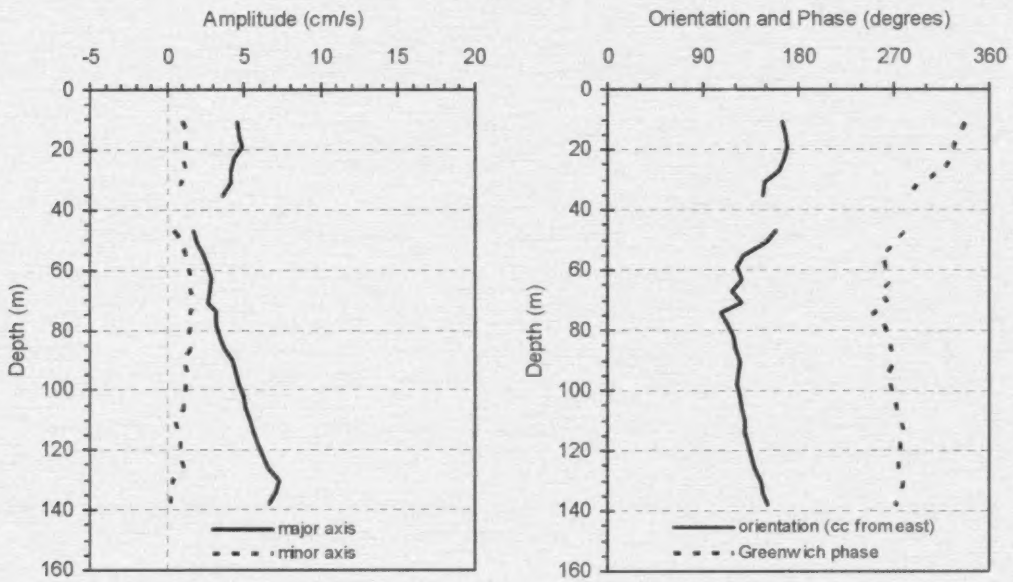


Figure 33: P1 Tidal Constituent, South Side of Barrow Strait

For Ice Free Period (Aug. 10, 2010 to Oct. 6, 2010):



For Solid Ice Period

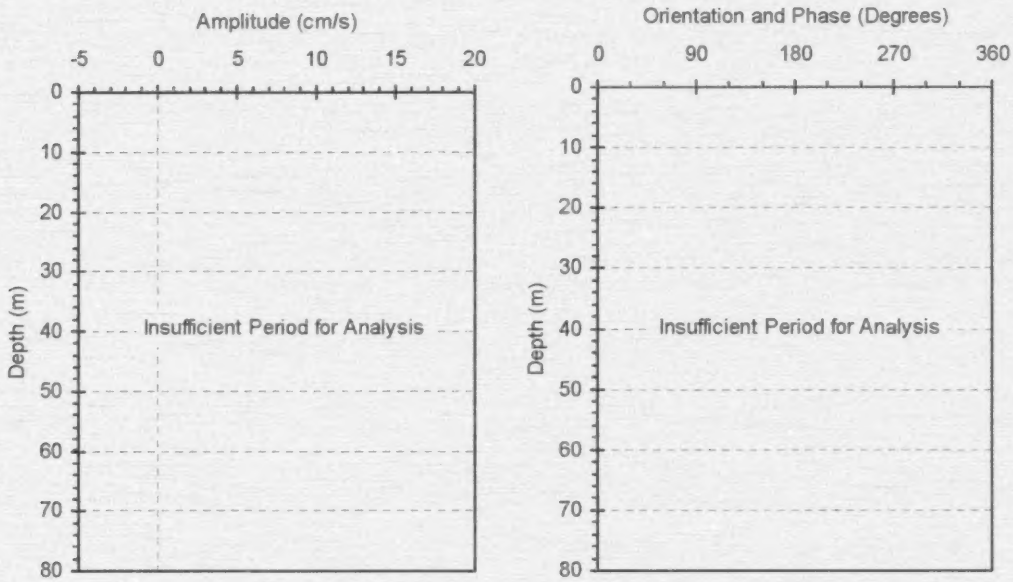
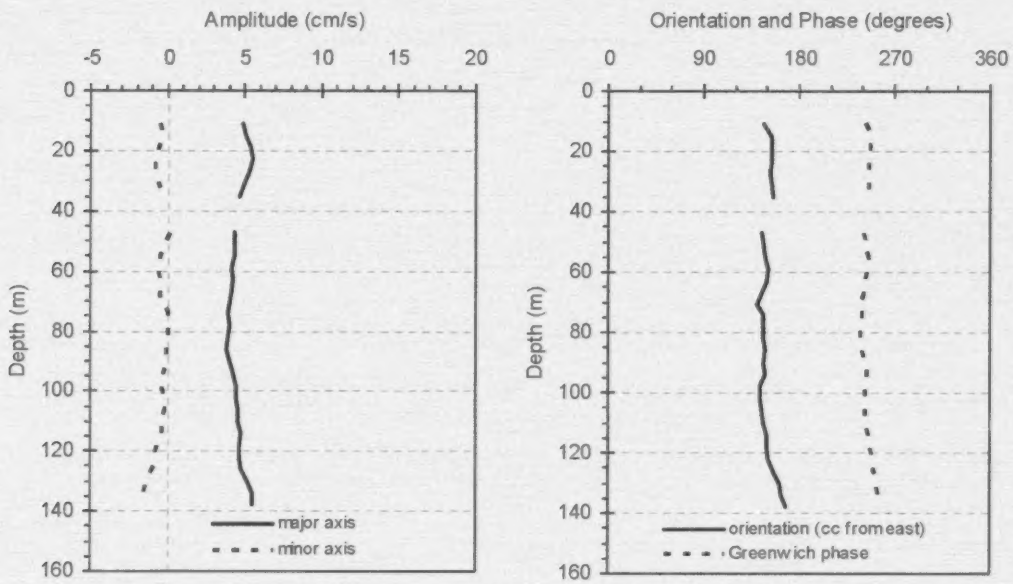


Figure 34: S2 Tidal Constituent, South Side of Barrow Strait

For Ice Free Period (Aug. 10, 2010 to Oct. 6, 2010):



For Solid Ice Period

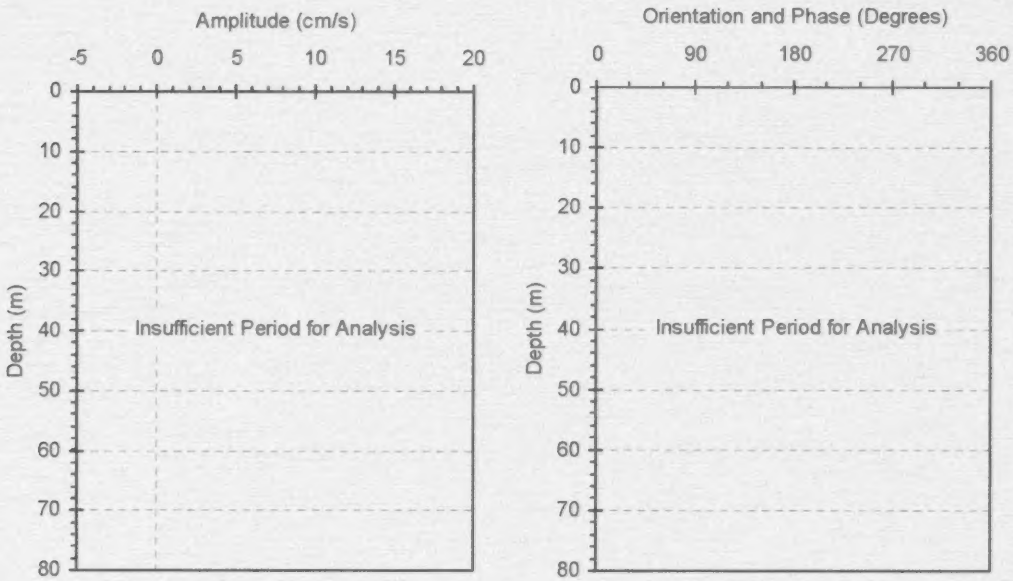
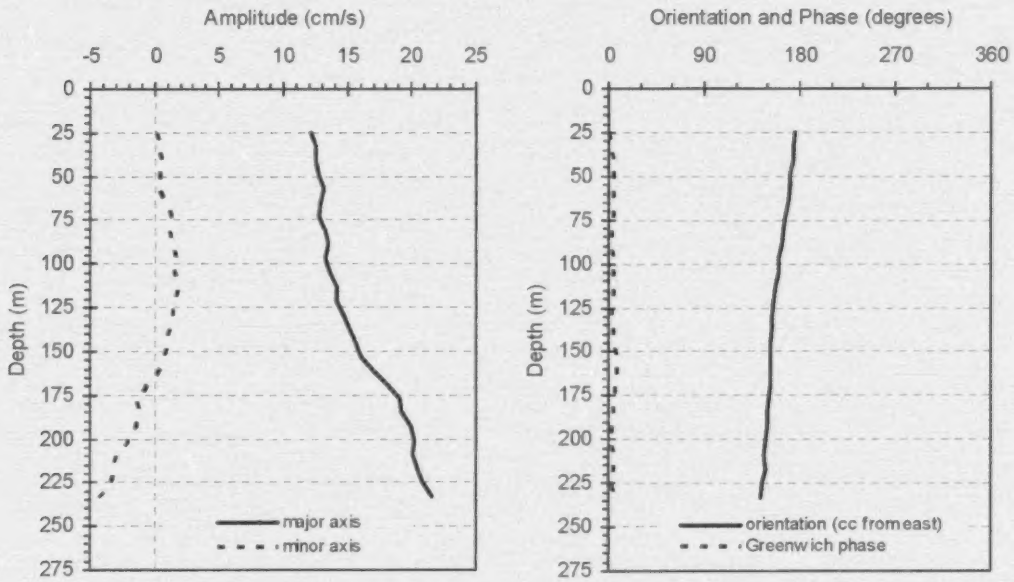


Figure 35: K1 Tidal Constituent, South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
major axis
minor axis
Orientation and Phase (degrees)
0 90 180 270 360
orientation (cc from east)
Greenwich phase

For Solid Ice Period

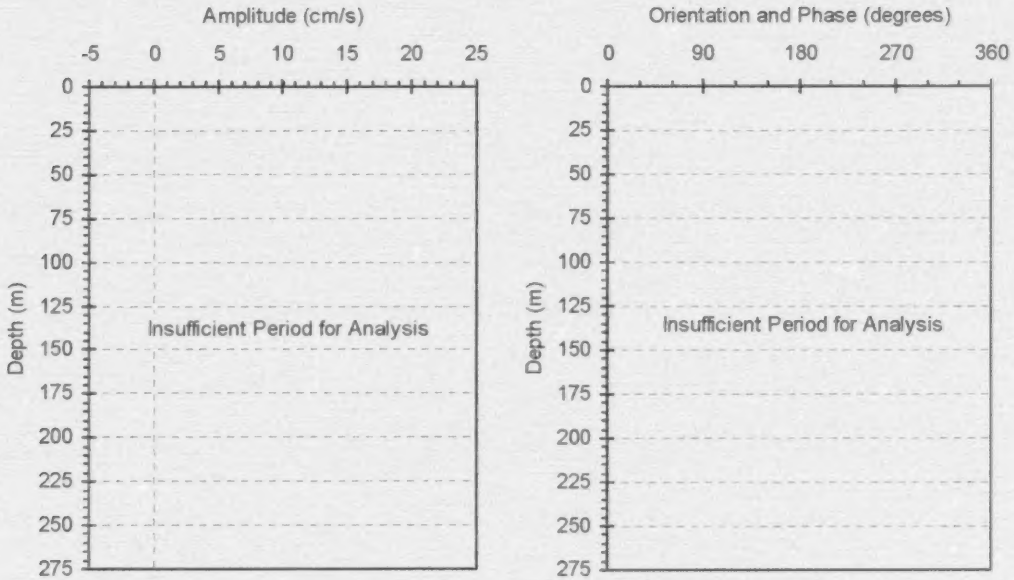
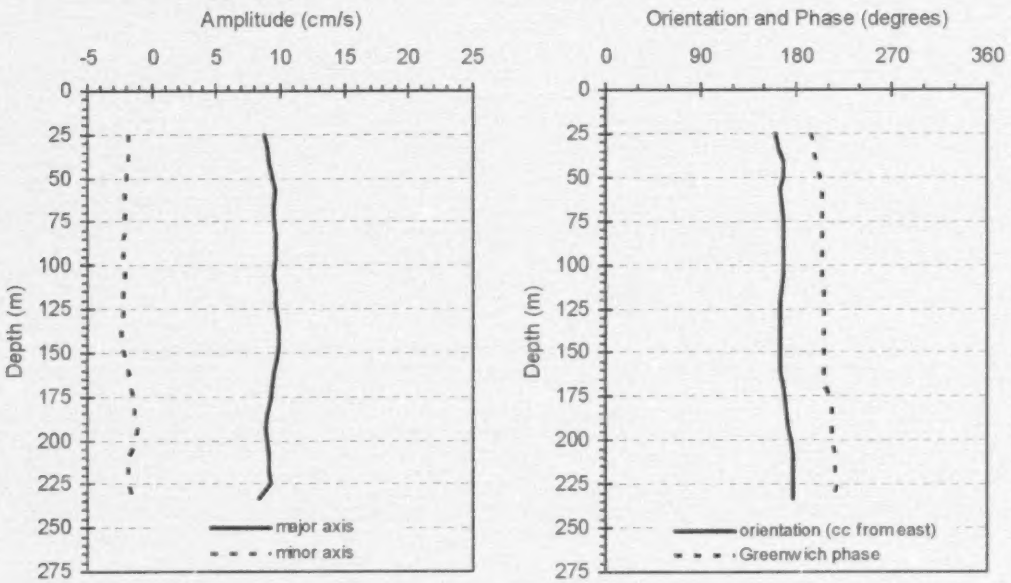

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
Insufficient Period for Analysis
Orientation and Phase (degrees)
0 90 180 270 360
Insufficient Period for Analysis

Figure 36: M2 Tidal Constituent, South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
major axis
minor axis
Orientation and Phase (degrees)
0 90 180 270 360
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
orientation (cc from east)
Greenwich phase

For Solid Ice Period

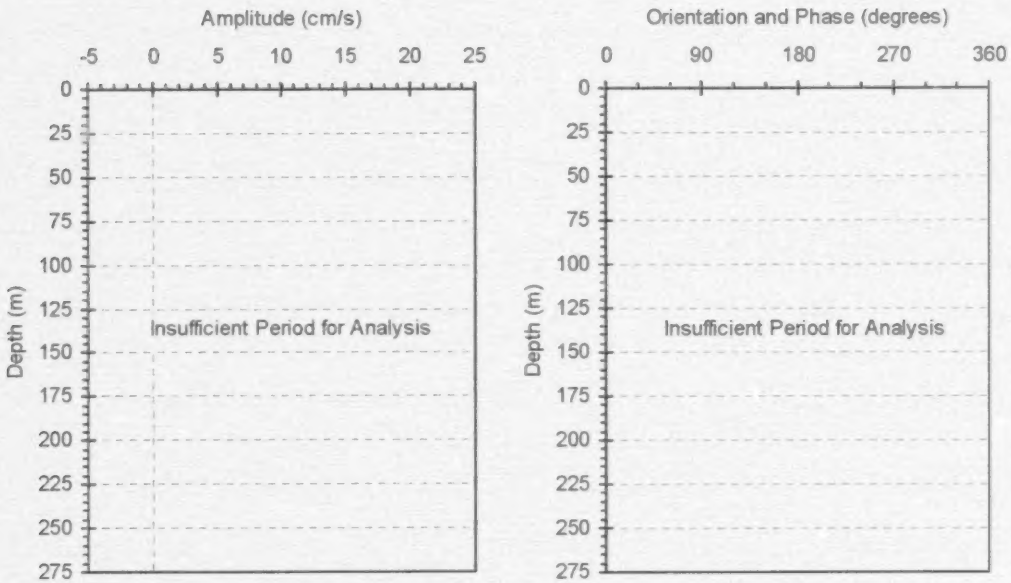
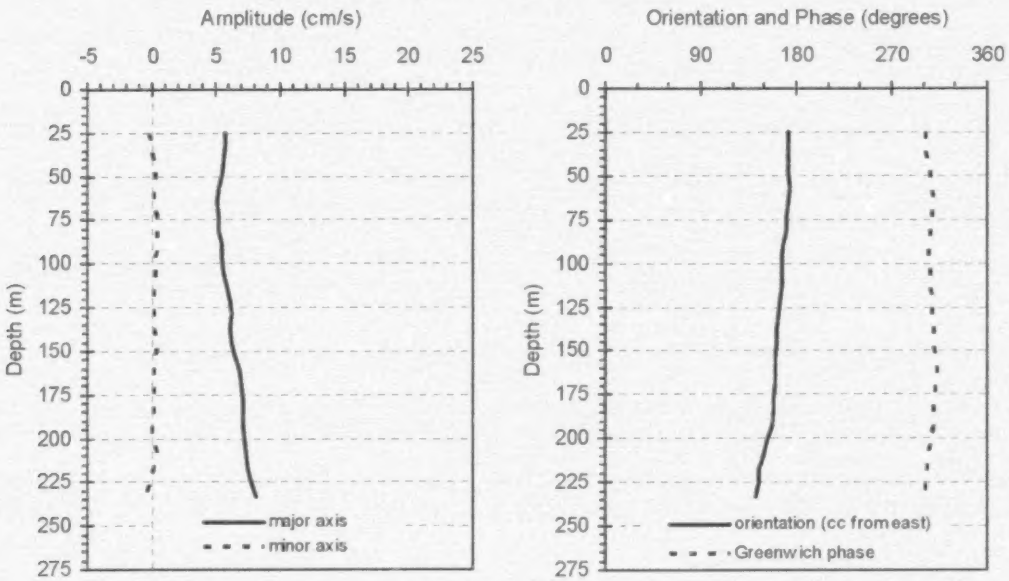

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
Insufficient Period for Analysis
Orientation and Phase (degrees)
0 90 180 270 360
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
Insufficient Period for Analysis

Figure 37: O1 Tidal Constituent, South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
major axis
minor axis
Orientation and Phase (degrees)
0 90 180 270 360
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
orientation (cc from east)
Greenwich phase

For Solid Ice Period

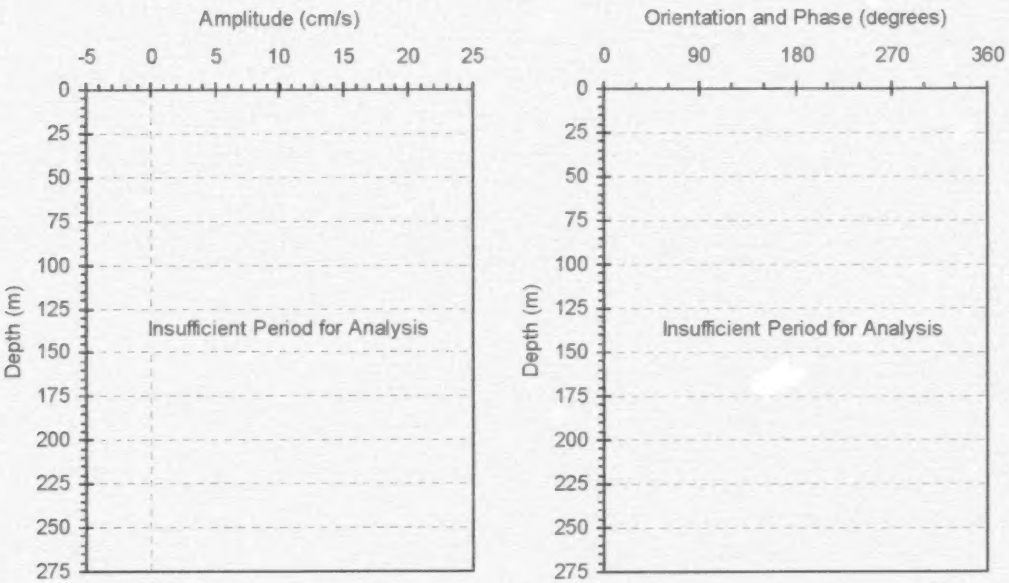
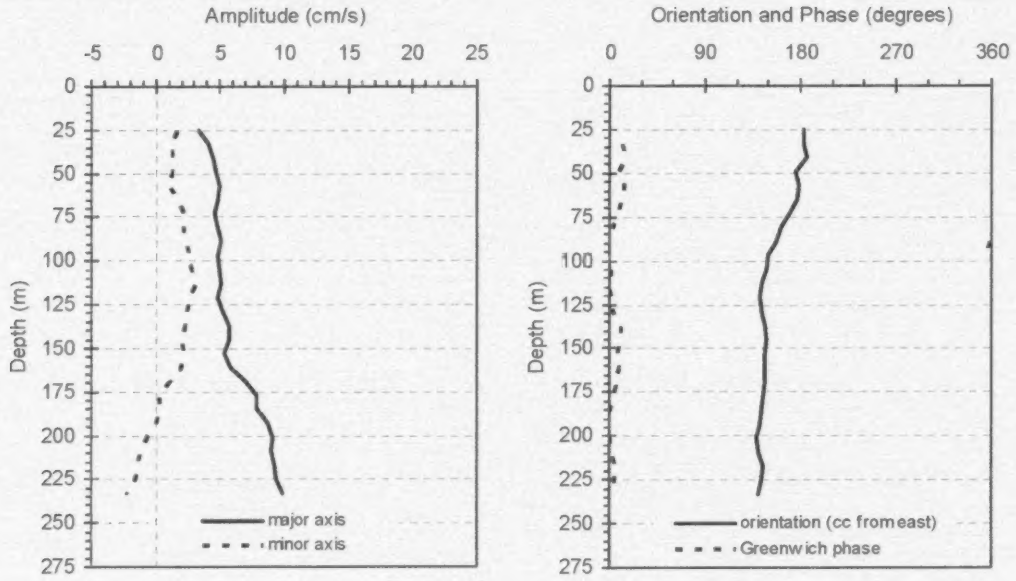

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
Insufficient Period for Analysis
Orientation and Phase (degrees)
0 90 180 270 360
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
Insufficient Period for Analysis

Figure 38: P1 Tidal Constituent, South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
major axis
minor axis
Orientation and Phase (degrees)
0 90 180 270 360
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
orientation (cc from east)
Greenwich phase

For Solid Ice Period

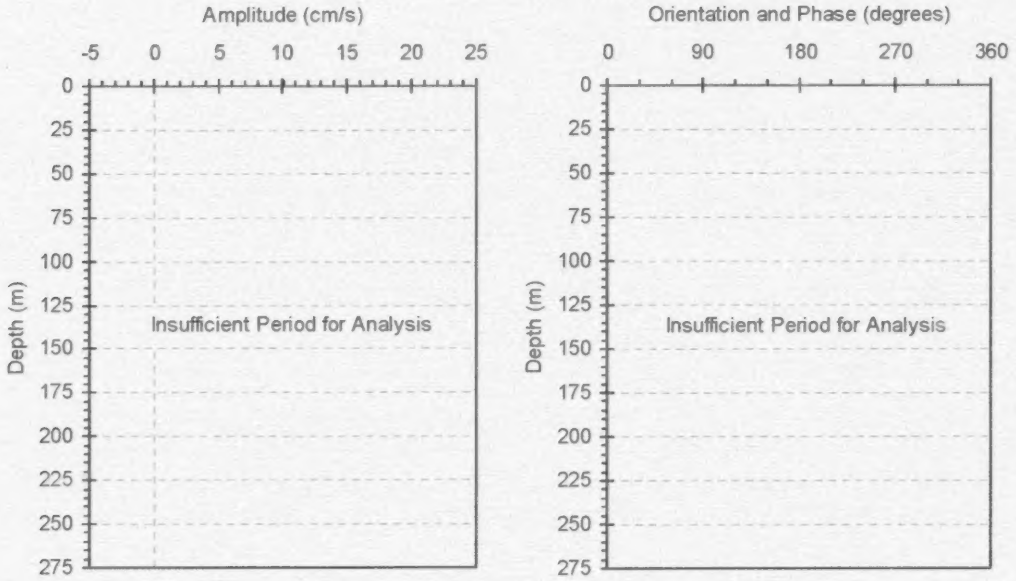
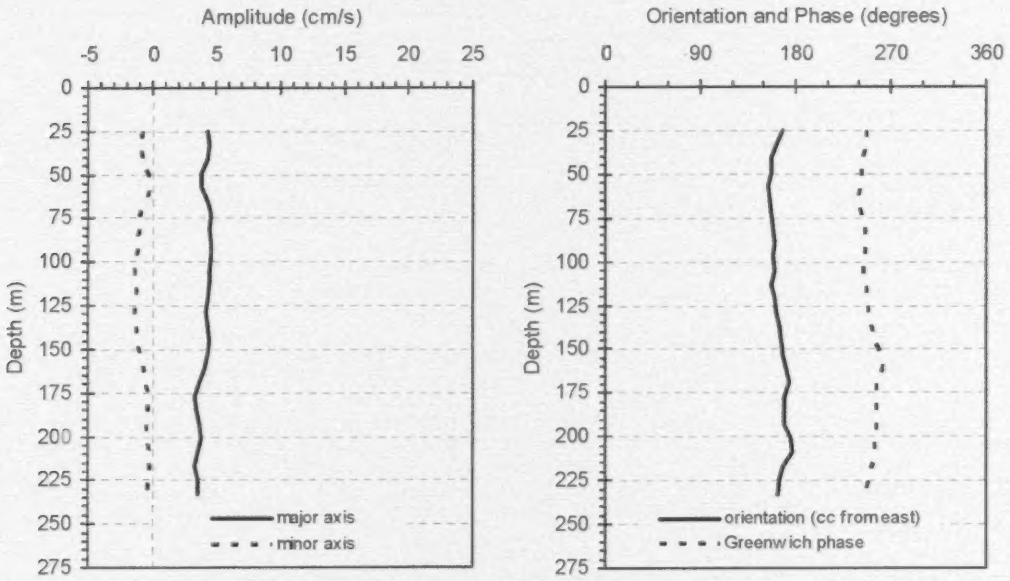

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
Insufficient Period for Analysis
Orientation and Phase (degrees)
0 90 180 270 360
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
Insufficient Period for Analysis

Figure 39: S2 Tidal Constituent, South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
major axis
minor axis
Orientation and Phase (degrees)
0 90 180 270 360
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
orientation (cc from east)
Greenwich phase

For Solid Ice Period

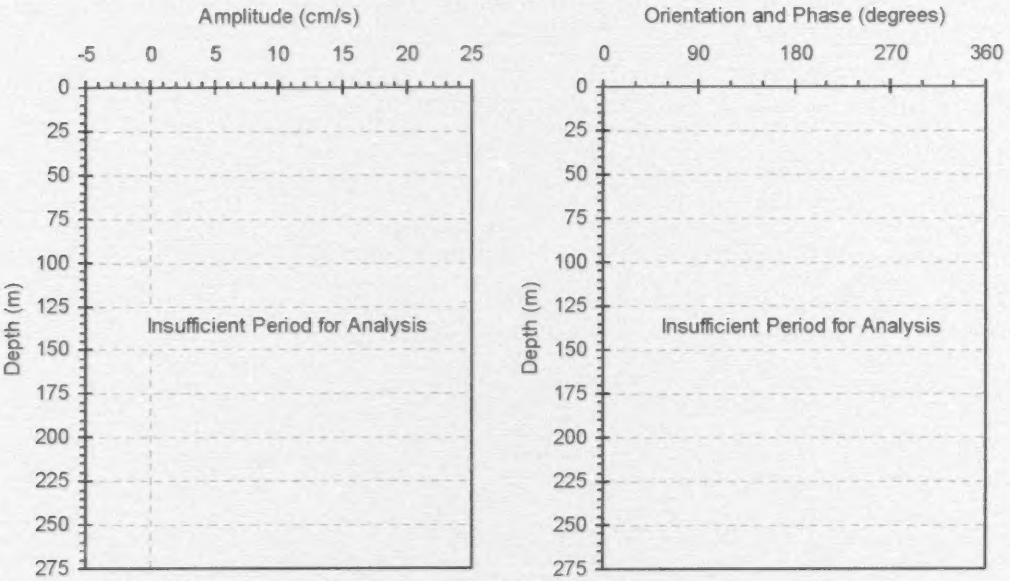
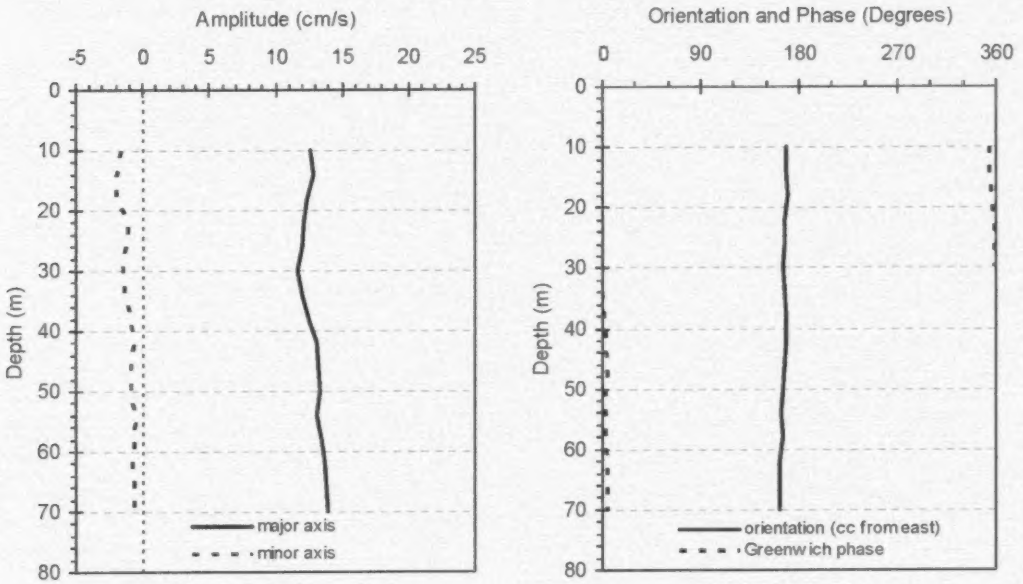

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
Insufficient Period for Analysis
Orientation and Phase (degrees)
0 90 180 270 360
Depth (m)
0 25 50 75 100 125 150 175 200 225 250 275
Insufficient Period for Analysis

Figure 40: K1 Tidal Constituent, South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
major axis
minor axis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
orientation (cc from east)
Greenwich phase

For Solid Ice Period

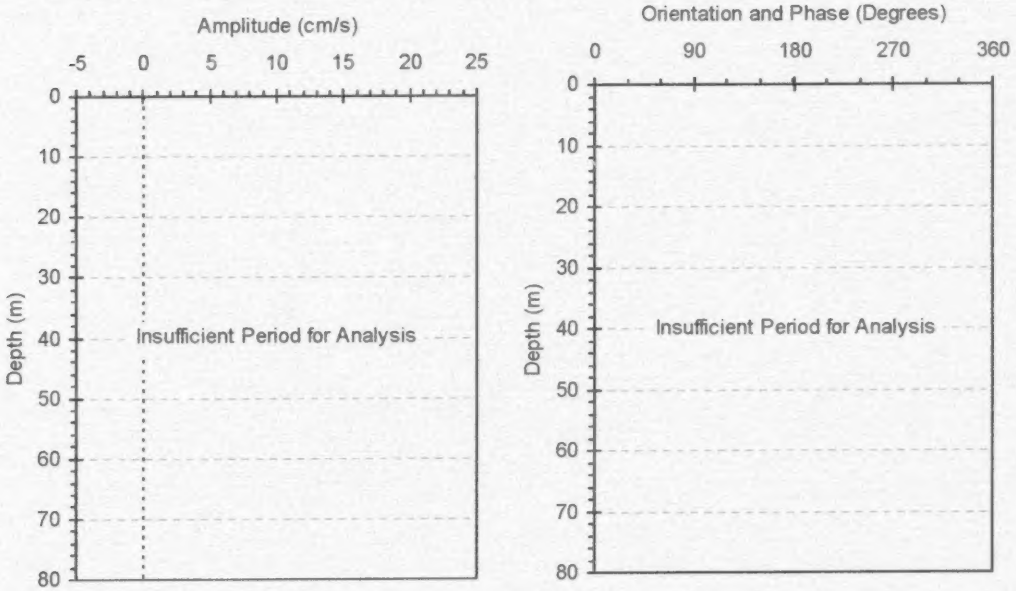
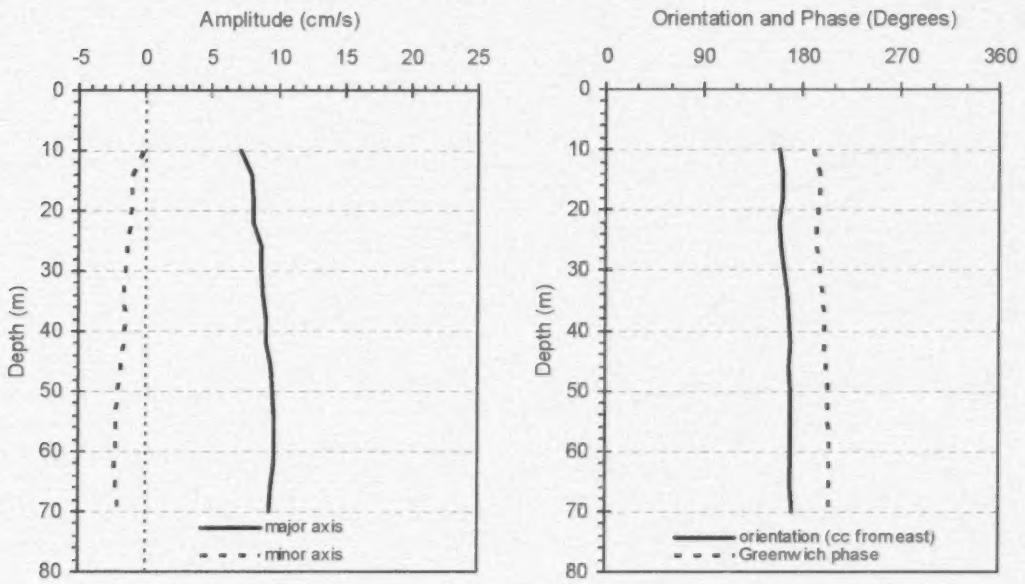

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis

Figure 41: M2 Tidal Constituent, South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
major axis
minor axis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
orientation (cc from east)
Greenwich phase

For Solid Ice Period

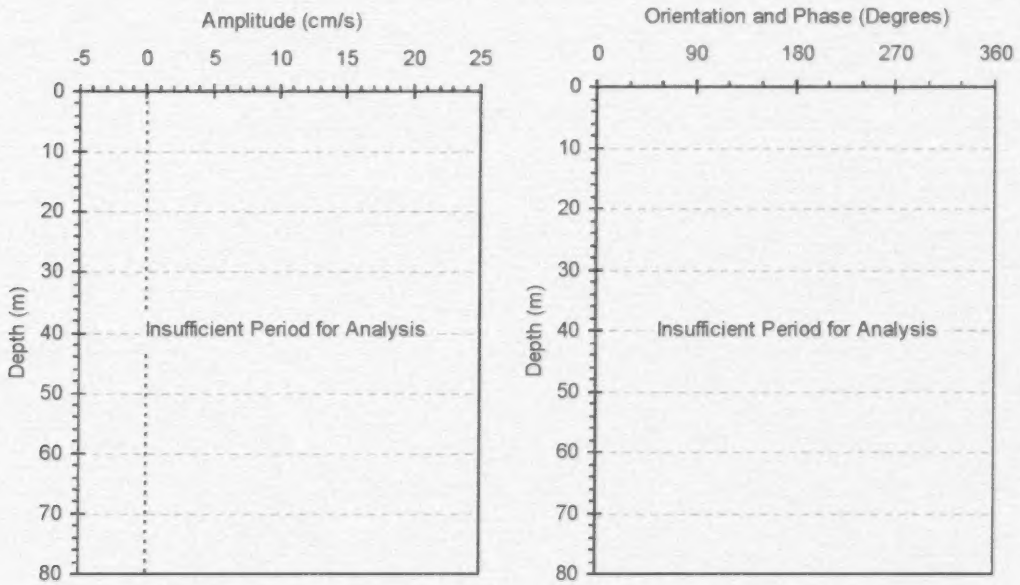
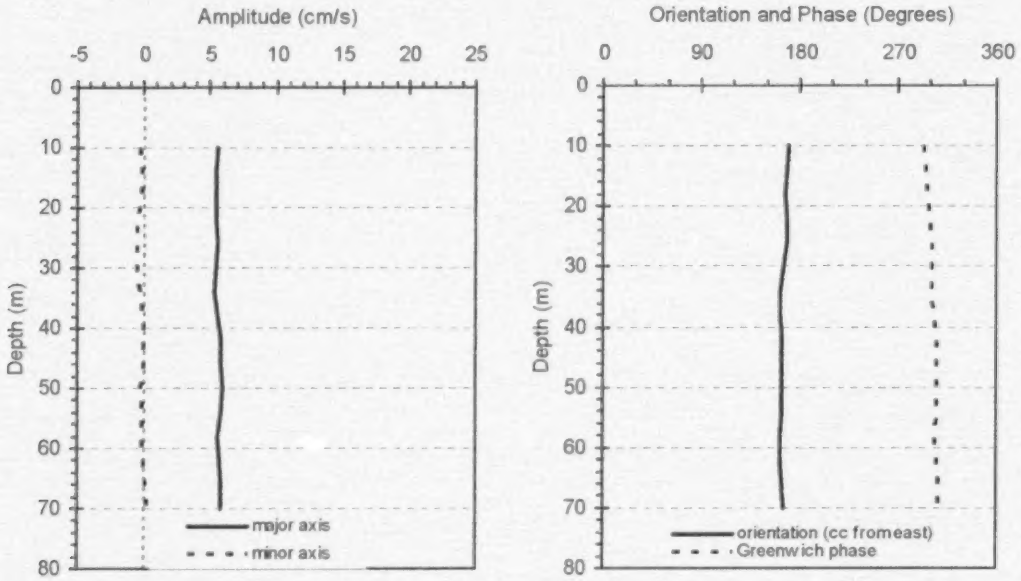

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis

Figure 42: O1 Tidal Constituent, South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
major axis
minor axis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
orientation (cc fromeast)
Greenwich phase

For Solid Ice Period

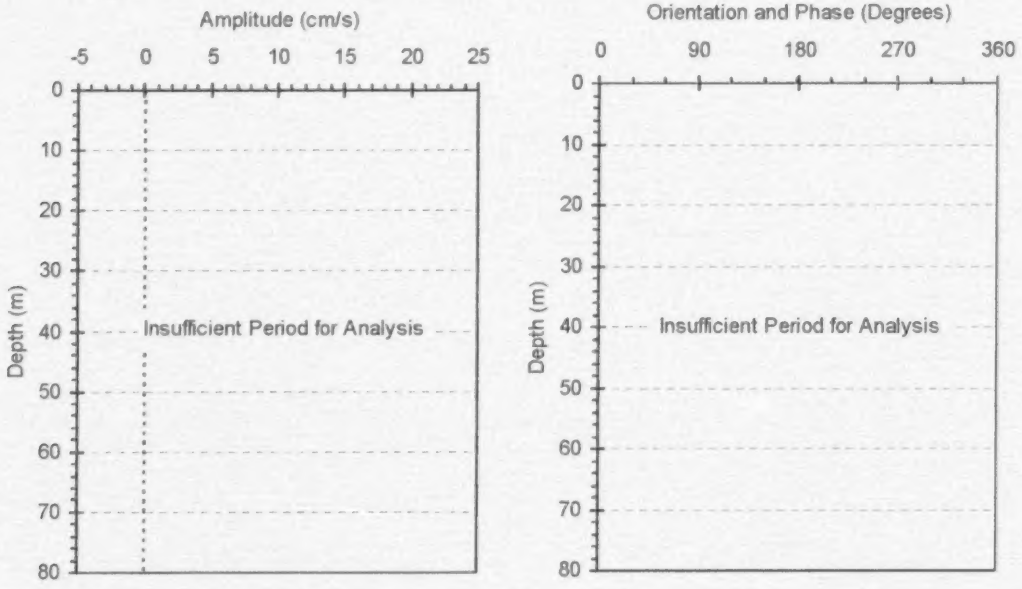
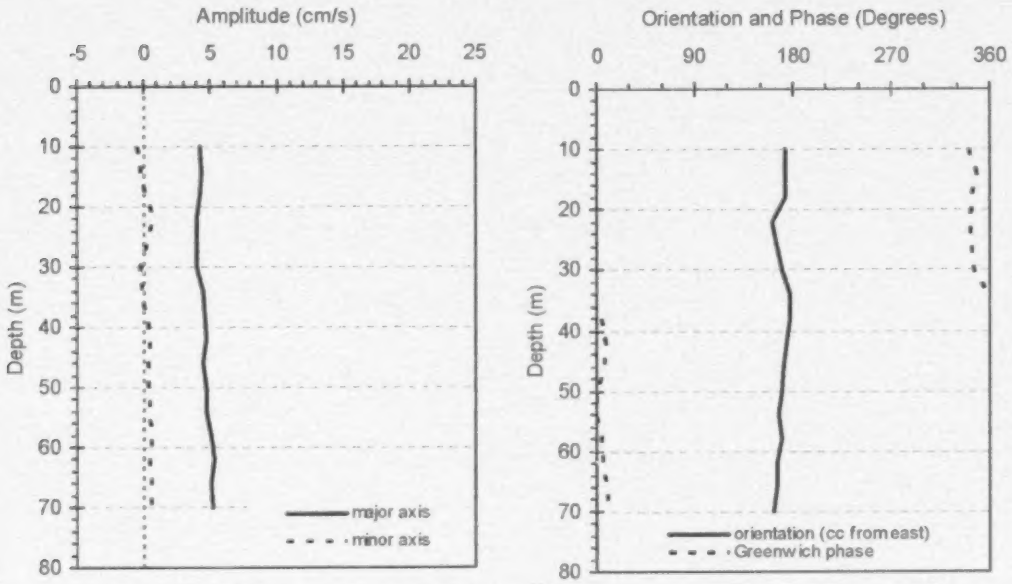

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis

Figure 43: P1 Tidal Constituent, South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
major axis
minor axis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
orientation (cc from east)
Greenwich phase

For Solid Ice Period

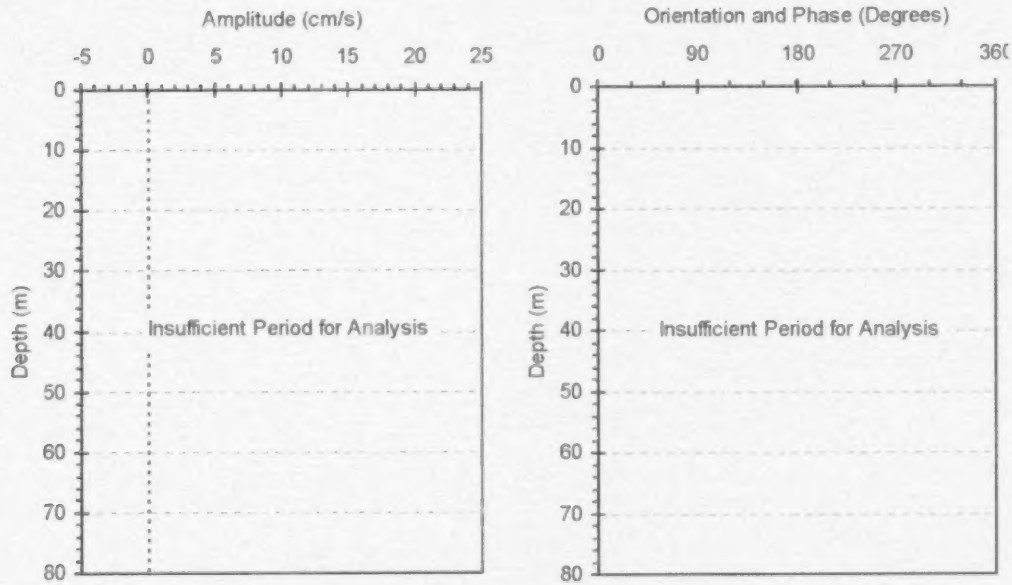
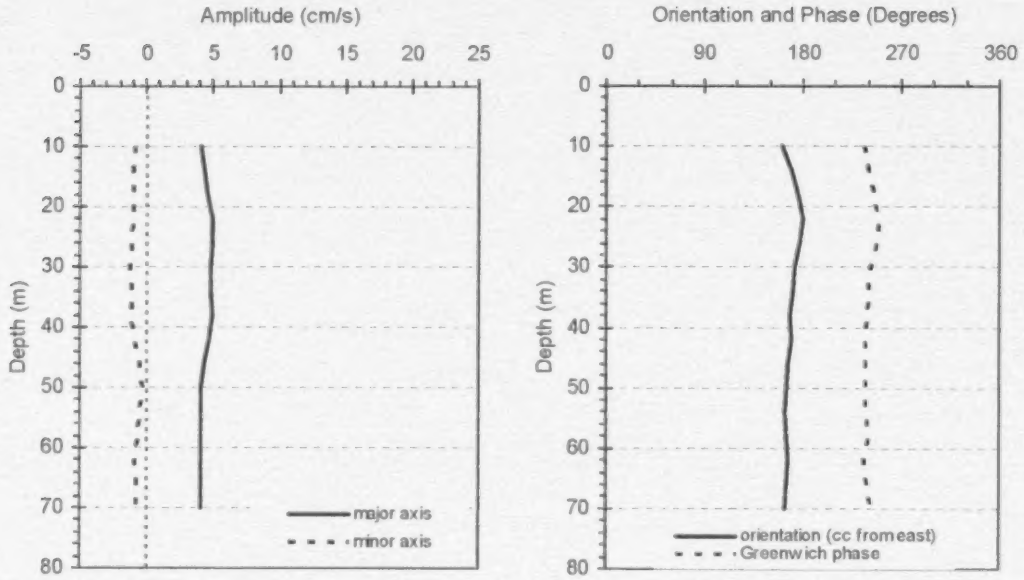

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis

Figure 44: S2 Tidal Constituent, South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 to Oct. 9, 2010):


Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
major axis
minor axis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
orientation (cc from east)
Greenwich phase

For Solid Ice Period

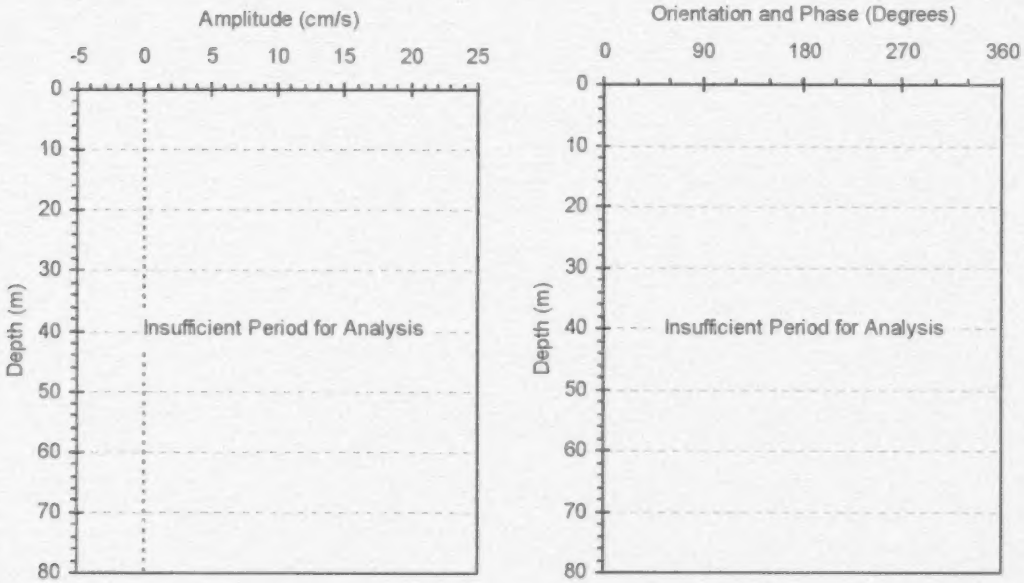

Amplitude (cm/s)
-5 0 5 10 15 20 25
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis
Orientation and Phase (Degrees)
0 90 180 270 360
Depth (m)
0 10 20 30 40 50 60 70 80
Insufficient Period for Analysis

Figure 45: Ice velocity data, South side of Barrow Strait
August 2010 – August 2011

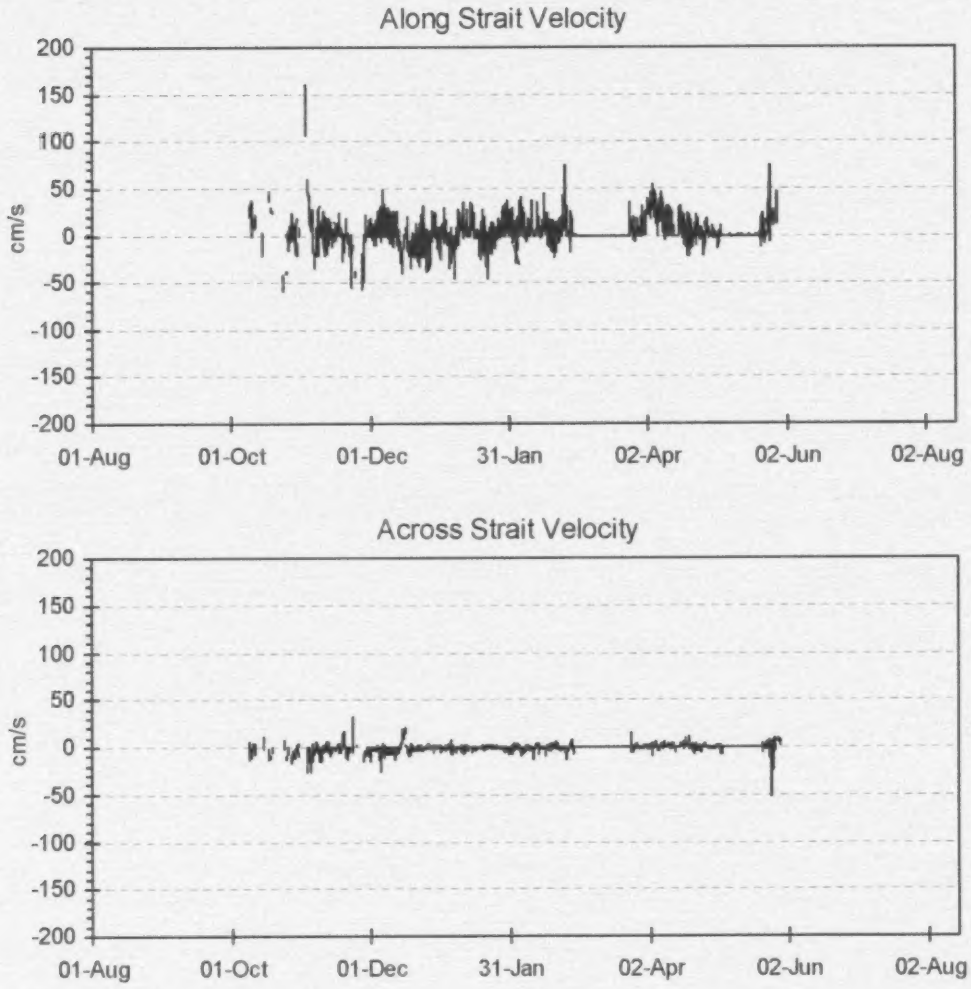


Figure 46: Ice velocity data, South Central Barrow Strait (Workhorse ADCP) August 2010 – August 2011

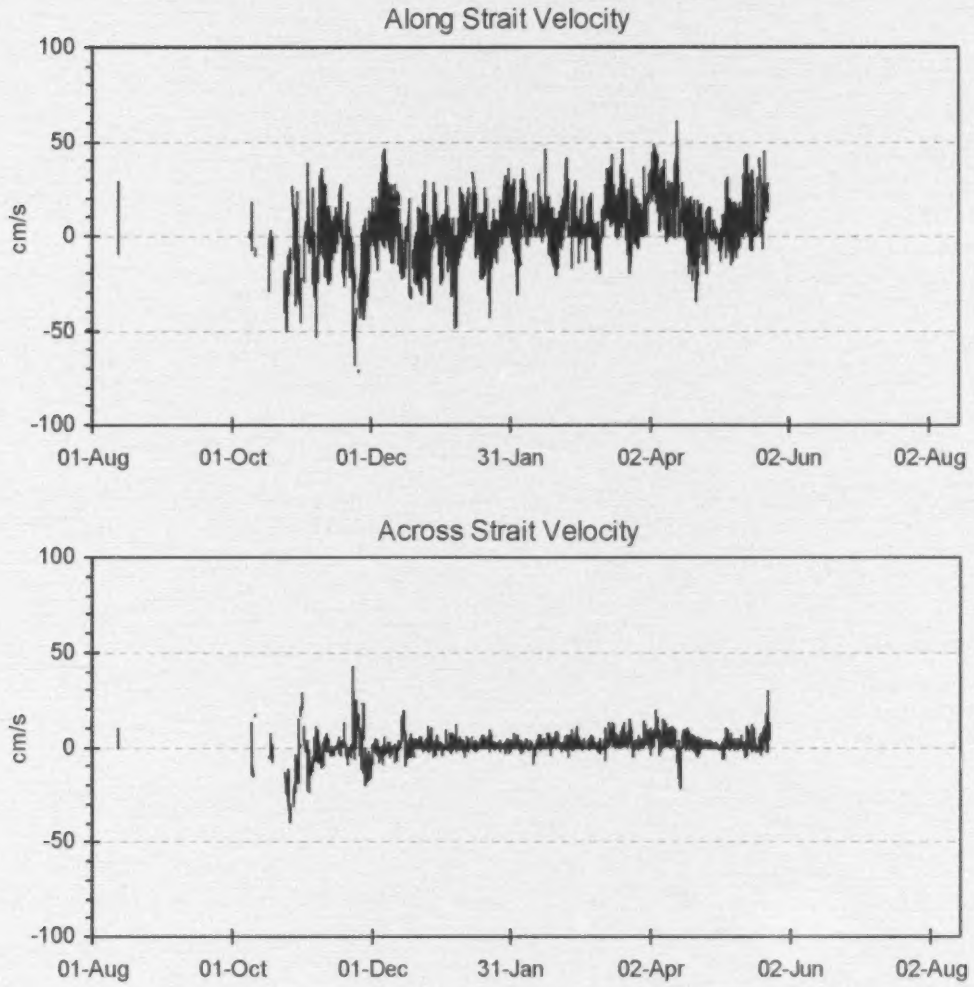


Figure 47: Ice Draft Statistics from Ice Profiling Sonar
South-Central Barrow Strait, August 2010 – July 2011

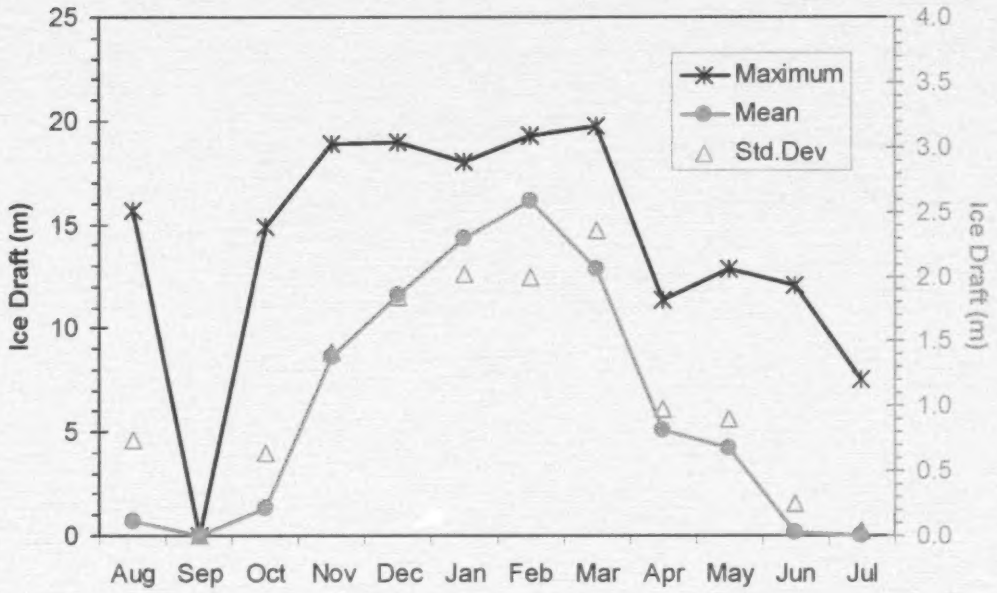


Figure 48: Frequency of Occurrence vs. Ice Draft in meters
South-Central Barrow Strait, August 2010 – July 2011

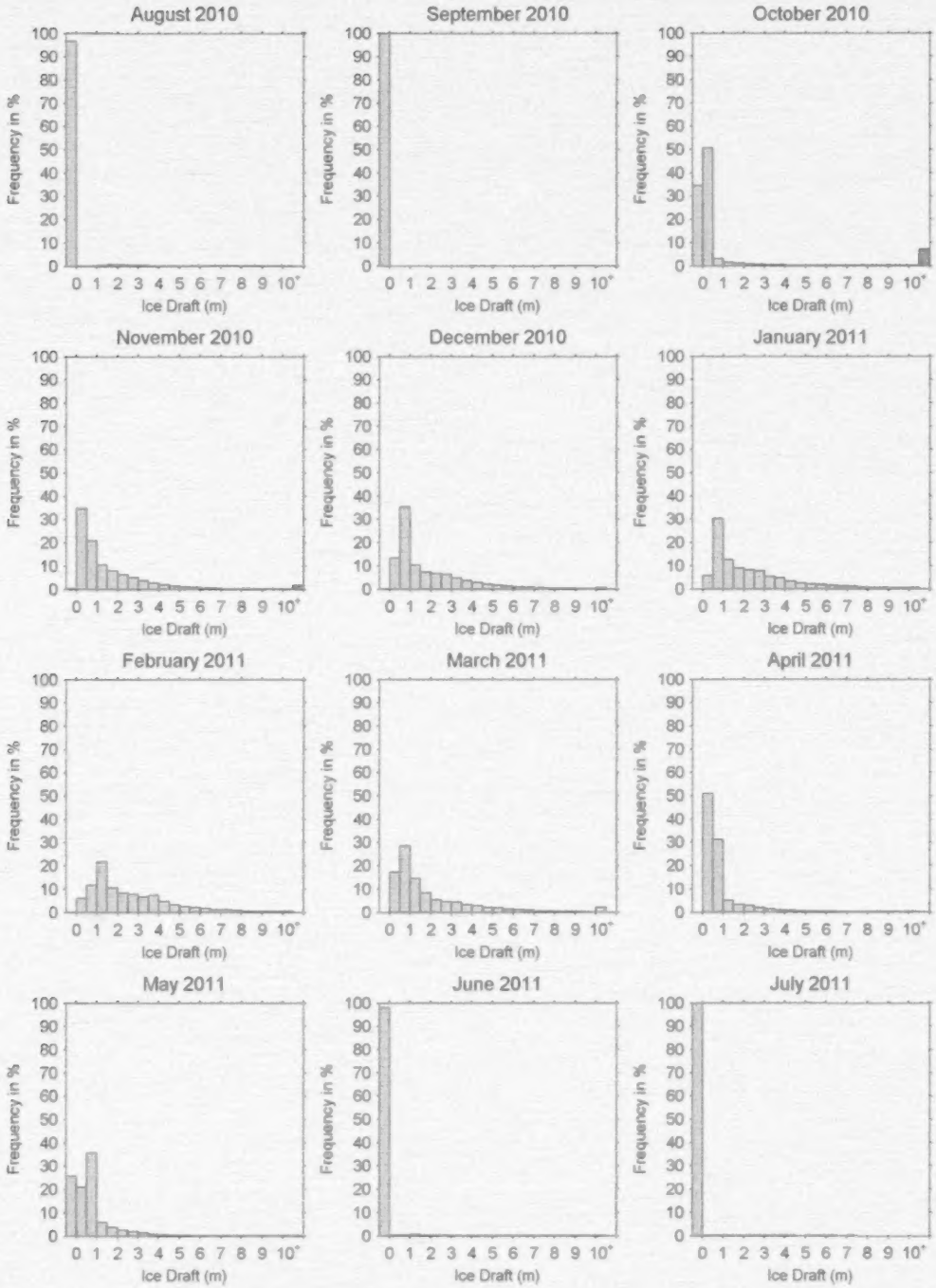


Table 1: Mooring Summary, 2010-2011

South Barrow Strait

BIO Consecutive Mooring Number	Instrument Type	Moored Depth (m)	Sounding (m)	Latitude (°N)	Longitude (°W)	Start Date-Time (UTC)	End Date-Time (UTC)	Sampling Interval (Seconds)
1772	MCTD	40	149	74.08308	-91.04250	10-Aug-2010 13:30	07-Aug-2011 13:30	1800
1772	WHADCP	77	149	74.08308	-91.04250	10-Aug-2010 14:00	07-Aug-2011 12:00	7200
1772	MCTD	79	149	74.08308	-91.04250	10-Aug-2010 13:30	07-Aug-2011 13:30	1800
1773	WHADCP	144	148	74.08165	-91.03272	10-Aug-2010 16:00	07-Aug-2011 12:00	7200
1773	MCTD	146	148	74.08165	-91.03272	10-Aug-2010 14:30	07-Aug-2011 12:30	1800

South Central Barrow Strait

BIO Consecutive Mooring Number	Instrument Type	Moored Depth (m)	Sounding (m)	Latitude (°N)	Longitude (°W)	Start Date-Time (UTC)	End Date-Time (UTC)	Sampling Interval (Seconds)
†1774	QMADCP	244	268	74.19578	-90.85275	11-Aug-2010 00:00	19-Jan-2011 06:00	7200
1774	MCTD	264	268	74.19578	-90.85275	10-Aug-2010 22:30	07-Aug-2011 14:30	1800
1775	MCTD	39	264	74.20423	-90.82792	10-Aug-2010 21:00	07-Aug-2011 17:00	1800
1775	WHADCP	76	264	74.20423	-90.82792	10-Aug-2010 22:00	07-Aug-2011 16:00	7200
1775	MCTD	154	264	74.20423	-90.82792	10-Aug-2010 21:00	07-Aug-2011 17:00	1800
1776	IPS	29	262	74.19623	-90.83650	10-Aug-2010 17:25	07-Aug-2011 16:20	3
1776	MCTD	56	262	74.19623	-90.83650	10-Aug-2010 16:00	07-Aug-2011 16:30	1800

† Data terminated early due to instrument failure.

Table 2: South Barrow Strait, Microcat/ADCP statistical summary
Late summer: August 10, 2010 - September 20, 2010

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
40	35	-1.31	0.19	-1.68	-0.72	31.84	0.16	31.39	32.29	25.60	0.13	25.23	25.96	14.84	18.80	-56.12	55.14	-1.36	6.29	-15.53	24.82
79	78	-1.44	0.11	-1.62	-0.95	32.39	0.11	32.07	32.69	26.05	0.09	25.79	26.30	10.06	18.22	-48.94	51.75	0.96	5.95	-20.60	22.98
146	138	-1.14	0.35	-1.63	-0.19	33.00	0.35	32.45	33.88	26.54	0.27	26.10	27.21	2.04	16.15	-50.75	37.26	0.55	5.39	-24.39	14.48

Table 3: South Central Barrow Strait, Microcat/ADCP statistical summary
Late summer: August 10, 2010 - September 20, 2010

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
39	38	-1.35	0.14	-1.54	-0.77	32.11	0.17	31.36	32.47	25.82	0.14	25.20	26.12	8.35	15.55	-34.63	50.99	1.17	9.69	-29.48	26.60
56	58	-1.44	0.08	-1.64	-1.03	32.36	0.12	31.91	32.58	26.03	0.10	25.65	26.21	7.43	15.37	-40.72	49.81	1.77	8.59	-23.92	24.80
154	153	-1.06	0.25	-1.42	-0.40	33.18	0.26	32.82	33.79	26.68	0.20	26.40	27.15	2.88	15.22	-31.76	43.50	2.06	6.99	-14.76	21.28
264	233	-0.11	0.08	-0.52	0.13	33.93	0.05	33.67	34.07	27.24	0.03	27.06	27.35	2.54	14.89	-44.90	41.20	5.88	8.50	-17.13	43.82

Table 4: South Barrow Strait, Microcat/ADCP statistical summary
Fall: September 21, 2010 - December 20, 2010

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
40	35	-1.42	0.21	-1.73	-0.58	31.84	0.36	30.72	33.03	25.61	0.29	24.69	26.56	2.68	23.72	-107.2	86.92	-2.08	6.77	-41.18	46.57
79	78	-1.38	0.14	-1.69	-0.59	32.57	0.22	32.12	33.63	26.20	0.17	25.83	27.03	3.56	20.55	-64.91	59.30	0.00	5.74	-20.10	25.32
146	138	-0.68	0.42	-1.48	0.18	33.43	0.41	32.48	34.00	26.87	0.32	26.12	27.29	1.94	16.56	-47.01	41.54	0.02	5.43	-19.60	15.76

Table 5: South Central Barrow Strait, Microcat/ADCP statistical summary
Fall: September 21, 2010 - December 20, 2010

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
39	38	-1.45	0.23	-1.74	-0.60	31.77	0.34	30.98	32.40	25.55	0.28	24.91	26.06	-0.80	15.96	-46.89	55.13	-0.14	6.99	-30.83	29.17
56	58	-1.46	0.10	-1.73	-0.97	32.18	0.24	31.15	32.57	25.88	0.19	25.05	26.20	-0.62	15.64	-49.26	57.43	0.49	6.72	-23.43	25.92
154	153	-0.82	0.21	-1.33	-0.16	33.44	0.21	32.87	33.88	26.88	0.17	26.44	27.21	4.03	15.19	-37.87	43.46	3.28	6.33	-16.45	24.00
264	233	0.10	0.22	-0.68	0.67	33.98	0.08	33.52	34.17	27.28	0.05	26.94	27.41	4.40	14.92	-45.45	43.97	8.70	7.06	-9.69	35.43

Table 6: South Barrow Strait, Microcat/ADCP statistical summary
Winter: December 21, 2010 - March 20, 2011

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
40	35	-1.73	0.03	-1.77	-1.53	32.02	0.22	31.65	32.39	25.76	0.18	25.45	26.06	6.62	13.59	-42.10	46.38	-1.47	3.55	-17.90	8.62
79	78	-1.45	0.12	-1.76	-0.79	32.43	0.12	31.99	33.20	26.09	0.10	25.73	26.70	10.58	16.26	-64.29	49.61	-0.30	5.14	-27.98	17.16
146	138	-0.82	0.49	-1.69	0.31	33.21	0.49	32.36	34.02	26.69	0.38	26.03	27.30	4.70	15.63	-44.38	39.76	-0.01	4.90	-21.47	14.46

Table 7: South Central Barrow Strait, Microcat/ADCP statistical summary
Winter: December 21, 2010 - March 20, 2011

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
39	38	-1.74	0.02	-1.77	-1.46	31.97	0.23	31.50	32.40	25.72	0.18	25.33	26.07	5.43	13.63	-40.25	42.44	1.41	3.65	-12.45	17.11
56	58	-1.69	0.10	-1.77	-1.20	32.06	0.19	31.62	32.49	25.79	0.15	25.43	26.13	5.05	14.21	-43.67	45.57	1.34	4.25	-14.91	16.20
154	153	-0.81	0.25	-1.36	0.10	33.40	0.30	32.64	34.03	26.85	0.23	26.25	27.34	Instrument Failed, January 19, 2011							
264	233	0.30	0.17	-0.85	0.70	34.02	0.07	33.27	34.14	27.30	0.04	26.74	27.42								

Table 8: South Barrow Strait, Microcat/ADCP statistical summary
Spring: March 21, 2011 - June 20, 2011

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
40	35	-1.58	0.22	-1.77	-0.32	32.28	0.13	31.69	32.75	25.97	0.10	25.46	26.35	13.87	14.12	-34.96	49.47	-1.28	5.11	-15.61	24.55
79	78	-1.58	0.13	-1.77	-0.79	32.50	0.10	32.22	32.94	26.14	0.08	25.90	26.50	9.93	14.82	-44.57	50.20	0.22	5.14	-18.13	18.63
146	138	-1.29	0.15	-1.72	-0.84	32.86	0.23	32.42	33.45	26.43	0.18	26.08	26.90	3.74	13.57	-38.48	39.62	-0.03	5.07	-17.37	15.63

Table 9: South Central Barrow Strait, Microcat/ADCP statistical summary
Spring: March 21, 2011 - June 20, 2011

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
39	38	-1.61	0.18	-1.77	-0.45	32.42	0.14	31.83	32.81	26.08	0.11	25.60	26.40	11.91	13.55	-30.15	51.19	3.19	7.78	-32.04	42.18
56	58	-1.63	0.13	-1.77	-0.91	32.51	0.12	32.16	32.83	26.15	0.09	25.87	26.41	11.25	13.86	-26.51	53.93	3.23	7.41	-25.53	37.50
154	153	-1.19	0.10	-1.51	-0.74	33.11	0.17	32.68	33.60	26.63	0.14	26.29	27.02	Instrument Failed, January 19, 2011							
264	233	-0.04	0.21	-0.89	0.31	33.89	0.09	33.51	34.03	27.21	0.06	26.94	27.31								

Table 10: South Barrow Strait, Microcat/ADCP statistical summary
Early Summer: June 21, 2011 - August 7, 2011

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
40	35	-1.04	0.51	-1.65	0.76	32.25	0.18	31.39	33.09	25.92	0.16	25.21	26.62	19.00	14.64	-26.61	67.39	-2.32	6.56	-20.36	22.26
79	78	-1.42	0.06	-1.69	-1.10	32.64	0.10	32.32	32.98	26.26	0.08	26.00	26.53	14.87	14.58	-32.56	63.05	0.18	4.85	-14.25	24.08
146	138	-1.21	0.10	-1.41	-0.83	33.06	0.23	32.52	33.52	26.59	0.18	26.15	26.95	4.64	15.42	-41.35	34.70	-0.19	5.65	-22.43	16.55

Table 11: South Central Barrow Strait, Microcat/ADCP statistical summary
Early Summer: June 21, 2011 - August 7, 2011

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
39	38	-1.00	0.50	-1.58	0.96	32.33	0.21	31.01	32.71	25.99	0.18	24.93	26.31	6.08	15.40	-28.98	53.27	0.68	7.93	-27.90	20.53
56	58	-1.35	0.30	-1.58	0.65	32.57	0.15	31.63	32.80	26.20	0.13	25.36	26.38	5.43	14.96	-29.89	50.66	1.44	6.97	-17.07	20.91
154	153	-1.23	0.11	-1.51	-0.74	33.35	0.09	32.95	33.65	26.82	0.07	26.50	27.05	Instrument Failed, January 19, 2011							
264	233	-0.23	0.11	-0.90	-0.04	33.79	0.04	33.45	33.86	27.14	0.03	26.87	27.19								

Table 12: South Barrow Strait, Microcat/ADCP statistical summary
Complete Record: August 10, 2010 - August 7, 2011

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
40	35	-1.48	0.33	-1.77	0.76	32.05	0.30	30.72	33.09	25.78	0.25	24.69	26.62	10.03	18.44	-107.2	86.92	-1.67	5.62	-41.18	46.57
79	78	-1.46	0.14	-1.77	-0.59	32.51	0.17	31.99	33.63	26.15	0.13	25.73	27.03	9.16	17.50	-64.91	63.05	0.11	5.37	-27.98	25.32
146	138	-0.99	0.43	-1.72	0.31	33.13	0.43	32.36	34.02	26.64	0.33	26.03	27.30	3.45	15.45	-50.75	41.54	0.03	5.24	-24.39	16.55

Table 13: South Central Barrow Strait, Microcat/ADCP statistical summary
Complete Record: August 10, 2010 - August 7, 2011

Depth (m)		Temperature (°C)				Salinity (ppt)				Density (Sigma-T)				Along-Strait Velocity (cm/s)				Cross-Strait Velocity (cm/s)			
Micro Cat	ADCP	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max
39	38	-1.49	0.33	-1.77	0.96	32.10	0.35	30.98	32.81	25.82	0.28	24.91	26.40	5.93	15.38	-46.89	55.13	1.35	7.17	-32.04	42.18
56	58	-1.54	0.19	-1.77	0.65	32.31	0.26	31.15	32.83	25.98	0.21	25.05	26.41	5.52	15.33	-49.26	57.43	1.67	6.75	-25.53	37.50
154	153	-1.00	0.27	-1.51	0.10	33.30	0.26	32.64	34.03	26.78	0.20	26.25	27.34	Instrument Failed, January 19, 2011							
264	233	0.04	0.25	-0.90	0.70	33.94	0.10	33.27	34.17	27.24	0.07	26.74	27.42								

Table 14: Tidal Constants for K1 Constituent

South Side Barrow Strait

For Ice Free Period (Aug. 10, 2010 – Oct. 6, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
11	9.74	-0.01	164	351
15	9.65	0.24	163	346
19	9.27	0.47	163	342
23	8.68	0.63	160	339
27	7.99	1.23	159	337
31	7.02	1.63	153	331
35	6.60	1.97	154	336
39	Data contaminated by presence of buoyancy package			
43				
47	6.76	1.33	152	343
51	6.61	1.21	155	339
55	6.51	1.51	157	336
59	6.93	1.88	158	334
63	7.27	2.13	159	333
67	7.08	2.31	161	334
71	7.28	2.06	158	331
74	7.12	2.87	163	330
78	7.40	3.00	158	327
82	7.53	2.86	155	323
86	7.80	3.24	153	320
90	8.12	3.32	149	316
94	8.16	3.55	148	315
98	8.38	3.89	147	315
102	8.57	3.89	147	313
106	8.91	3.78	147	314
110	9.36	3.49	145	313
114	9.72	3.82	143	311
118	9.99	3.86	145	310
122	10.22	3.92	146	309
126	10.77	3.77	148	309
130	11.68	2.97	148	308
134	11.87	2.64	149	306
138	11.46	2.05	150	302

For Solid Ice Period

Insufficient Period for Analysis

Table 14: Tidal Constants for K1 Constituent (continued)

South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
10	12.61	-1.56	168	354
14	12.90	-1.94	168	355
18	12.36	-1.94	170	355
22	12.16	-1.07	167	359
26	11.98	-1.29	166	358
30	11.58	-1.52	165	359
34	11.99	-1.39	167	0
38	12.52	-0.85	168	2
42	13.07	-0.64	168	3
46	13.21	-0.87	166	4
50	13.39	-0.92	165	3
54	13.15	-0.56	164	3
58	13.50	-0.68	165	3
62	13.72	-0.71	163	4
66	13.79	-0.64	163	5
70	14.01	-0.62	162	5

For Solid Ice Period

Insufficient Period for Analysis

Table 14: Tidal Constants for K1 Constituent (continued)

South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
25	12.09	0.21	176	0
33	12.51	0.27	175	3
41	12.48	0.59	174	4
49	12.83	0.45	171	4
57	13.17	0.27	171	5
65	12.93	0.83	170	5
73	12.80	1.30	166	4
81	13.28	1.21	164	4
89	13.49	1.37	163	3
97	13.28	1.64	161	4
105	13.65	1.57	160	4
113	14.14	1.89	157	5
121	14.20	1.59	156	5
129	14.66	1.38	155	4
137	15.23	1.20	154	5
145	15.64	0.89	153	6
153	16.09	0.74	152	7
161	17.09	0.26	152	8
169	18.12	-0.61	152	7
177	19.13	-1.40	151	6
185	19.25	-1.22	150	5
193	19.92	-1.47	150	3
201	20.20	-2.16	147	4
209	20.14	-2.94	147	4
217	20.42	-3.08	147	5
225	20.80	-3.38	146	4
233	21.62	-4.41	143	4

For Solid Ice Period

Insufficient Period for Analysis

Table 15: Tidal Constants for M2 Constituent

South Side Barrow Strait

For Ice Free Period (Aug. 10, 2010 – Oct. 6, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
11	8.22	-0.27	144	200
15	8.20	-0.10	143	200
19	8.56	-0.26	144	201
23	9.08	-0.31	145	202
27	8.89	-0.14	146	202
31	8.55	-0.02	146	202
35	8.44	-0.09	147	203
39	Data contaminated by presence of buoyancy package			
43				
47	8.53	0.08	150	202
51	8.63	0.22	148	201
55	8.74	0.20	147	201
59	9.07	0.06	148	200
63	9.38	-0.07	150	201
67	9.56	-0.27	151	201
71	9.60	-0.39	152	202
74	9.78	-0.57	158	202
78	9.78	-0.66	157	203
82	9.78	-0.46	156	204
86	9.80	-0.66	157	205
90	9.54	-0.90	157	206
94	9.58	-0.84	157	206
98	9.53	-0.88	156	206
102	9.50	-0.79	155	206
106	9.66	-0.75	155	206
110	9.90	-0.75	154	205
114	9.92	-0.72	155	205
118	10.02	-0.96	157	205
122	10.14	-1.01	160	207
126	10.34	-1.11	162	209
130	10.37	-1.18	165	211
134	10.38	-1.51	168	213
138	10.56	-1.35	171	214

For Solid Ice Period

Insufficient Period for Analysis

Table 15: Tidal Constants for M2 Constituent (continued)

South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
10	7.18	-0.17	159	190
14	8.03	-1.03	163	196
18	8.08	-0.95	162	196
22	8.13	-1.15	160	193
26	8.69	-1.35	160	193
30	8.78	-1.47	163	196
34	8.87	-1.55	167	199
38	9.03	-1.53	168	201
42	9.08	-1.63	169	201
46	9.41	-1.85	169	202
50	9.55	-2.04	169	203
54	9.72	-2.20	170	204
58	9.68	-2.25	170	205
62	9.66	-2.32	169	205
66	9.51	-2.24	170	205
70	9.36	-2.07	171	205

For Solid Ice Period

Insufficient Period for Analysis

Table 15: Tidal Constants for M2 Constituent (continued)

South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
25	8.69	-1.87	160	194
33	9.01	-1.86	164	197
41	9.16	-1.90	168	199
49	9.39	-2.00	167	201
57	9.58	-2.09	165	204
65	9.52	-2.11	166	205
73	9.44	-2.10	168	205
81	9.59	-2.08	168	205
89	9.62	-2.23	168	205
97	9.60	-2.18	168	205
105	9.53	-2.12	167	205
113	9.67	-2.23	166	206
121	9.65	-2.18	165	206
129	9.69	-2.18	165	206
137	9.83	-2.38	165	205
145	9.93	-2.22	164	206
153	9.77	-2.08	164	206
161	9.55	-1.89	165	206
169	9.33	-1.60	168	208
177	9.21	-1.42	170	211
185	8.94	-1.28	171	214
193	8.87	-1.14	172	214
201	8.96	-1.33	175	215
209	9.15	-1.71	176	216
217	9.08	-1.87	177	217
225	9.21	-1.85	177	217
233	8.36	-1.48	177	217

For Solid Ice Period

Insufficient Period for Analysis

Table 16: Tidal Constants for O1 Constituent

South Side Barrow Strait

For Ice Free Period (Aug. 10, 2010 – Oct. 6, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
11	3.51	-0.81	149	329
15	3.45	-0.76	149	324
19	3.32	-0.43	155	315
23	3.42	0.03	151	311
27	3.04	0.41	150	310
31	2.94	0.63	156	314
35	3.14	0.64	158	316
39	Data contaminated by presence of buoyancy package			
43				
47	3.80	0.43	152	299
51	3.79	0.29	149	296
55	3.90	0.33	144	293
59	3.95	0.29	142	292
63	4.04	-0.05	143	287
67	3.78	-0.07	143	285
71	3.87	0.07	142	283
74	3.87	0.09	146	277
78	4.09	0.02	147	277
82	4.04	0.03	146	276
86	4.05	0.08	147	276
90	4.09	0.09	148	276
94	4.15	0.25	149	274
98	4.41	0.32	150	276
102	4.55	0.37	151	278
106	4.53	0.43	153	278
110	4.51	0.49	156	280
114	4.58	0.66	156	278
118	4.79	0.92	157	276
122	5.10	0.98	158	277
126	5.33	0.94	159	279
130	5.59	0.82	162	281
134	5.63	0.71	165	282
138	5.82	0.87	166	280

For Solid Ice Period

Insufficient Period for Analysis

Table 16: Tidal Constants for O1 Constituent (continued)

South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
10	5.53	-0.26	169	294
14	5.40	-0.18	168	295
18	5.45	-0.09	167	297
22	5.47	-0.54	168	300
26	5.54	-0.52	169	302
30	5.42	-0.49	165	301
34	5.36	-0.26	162	301
38	5.62	0.02	163	303
42	5.81	0.02	164	305
46	5.75	-0.07	164	305
50	5.89	-0.22	164	305
54	5.78	-0.11	164	305
58	5.58	-0.11	162	305
62	5.66	-0.07	162	306
66	5.81	0.16	164	307
70	5.84	0.25	165	307

For Solid Ice Period

Insufficient Period for Analysis

Table 16: Tidal Constants for O1 Constituent (continued)

South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
25	5.73	-0.27	173	302
33	5.69	-0.11	173	302
41	5.62	0.20	172	303
49	5.43	0.32	173	306
57	5.21	0.16	175	308
65	5.05	0.22	172	309
73	5.17	0.46	171	308
81	5.25	0.38	170	306
89	5.40	0.37	168	305
97	5.47	0.32	166	304
105	5.65	0.33	167	307
113	5.89	0.20	166	307
121	6.16	0.16	164	308
129	6.27	0.18	163	308
137	6.07	0.22	162	310
145	6.16	0.51	162	310
153	6.41	0.28	161	312
161	6.86	0.16	160	312
169	7.01	0.23	159	311
177	7.06	0.21	158	311
185	7.12	0.13	158	310
193	7.11	0.06	156	309
201	7.17	0.17	153	307
209	7.34	0.45	149	305
217	7.52	0.23	145	304
225	7.79	-0.10	144	303
233	8.13	-0.41	142	302

For Solid Ice Period

Insufficient Period for Analysis

Table 17: Tidal Constants for P1 Constituent

South Side Barrow Strait

For Ice Free Period (Aug. 10, 2010 – Oct. 6, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
11	4.53	1.02	164	337
15	4.70	1.26	167	332
19	4.86	1.21	170	327
23	4.38	0.98	166	323
27	4.16	1.26	161	314
31	4.17	0.90	149	294
35	3.63	0.86	146	286
39	Data contaminated by presence of buoyancy package			
43				
47	1.72	0.49	159	279
51	1.90	0.99	150	270
55	2.33	1.16	128	258
59	2.68	1.37	122	262
63	2.87	1.49	127	267
67	2.82	1.53	117	256
71	2.67	1.71	127	264
74	3.19	1.52	107	250
78	3.19	1.64	112	259
82	3.44	1.45	119	265
86	3.71	1.46	121	267
90	4.28	1.14	125	270
94	4.50	1.27	123	266
98	4.67	1.19	122	267
102	5.01	1.19	125	268
106	5.09	1.09	126	273
110	5.37	0.58	130	278
114	5.66	0.64	129	279
118	5.88	0.92	133	276
122	6.24	1.04	136	274
126	6.61	1.05	138	275
130	7.25	0.39	144	279
134	7.12	0.24	147	276
138	6.64	0.21	151	271

For Solid Ice Period

Insufficient Period for Analysis

Table 17: Tidal Constants for P1 Constituent (continued)

South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
10	4.23	-0.48	173	342
14	4.37	-0.29	173	349
18	4.20	0.27	173	344
22	3.94	0.66	161	342
26	4.02	0.21	166	344
30	4.02	-0.21	170	345
34	4.49	-0.12	176	357
38	4.61	0.24	177	5
42	4.72	0.44	175	9
46	4.45	0.29	171	7
50	4.72	0.32	169	1
54	4.76	0.46	166	0
58	5.07	0.59	169	4
62	5.27	0.47	166	6
66	5.13	0.53	165	10
70	5.24	0.61	162	10

For Solid Ice Period

Insufficient Period for Analysis

Table 17: Tidal Constants for P1 Constituent (continued)

South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
25	3.32	1.72	183	358
33	4.12	1.36	184	12
41	4.43	1.32	186	16
49	4.69	1.34	176	9
57	4.99	1.09	179	13
65	4.84	1.70	177	12
73	4.56	2.18	169	8
81	4.81	2.21	162	4
89	5.09	2.34	157	359
97	4.84	2.60	149	358
105	4.98	2.82	149	2
113	5.06	3.04	143	1
121	4.87	2.70	142	2
129	5.18	2.44	144	3
137	5.66	2.26	147	10
145	5.73	2.08	148	10
153	5.40	2.21	147	8
161	5.85	1.89	146	9
169	6.92	1.04	146	6
177	7.89	0.34	145	5
185	7.84	0.28	143	0
193	8.72	-0.02	143	357
201	9.13	-0.73	139	0
209	9.05	-1.17	141	2
217	9.25	-1.31	144	5
225	9.40	-1.62	143	4
233	9.81	-2.40	140	7

For Solid Ice Period

Insufficient Period for Analysis

Table 18: Tidal Constants for S2 Constituent

South Side Barrow Strait

For Ice Free Period (Aug. 10, 2010 – Oct. 6, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
11	4.92	-0.53	146	242
15	5.06	-0.35	153	248
19	5.38	-0.55	153	247
23	5.49	-0.78	153	246
27	5.26	-0.78	153	245
31	5.02	-0.57	154	246
35	4.65	-0.35	155	246
39	Data contaminated by presence of buoyancy package			
43				
47	4.30	0.12	145	241
51	4.30	-0.12	146	243
55	4.31	-0.45	148	246
59	4.19	-0.62	151	246
63	4.24	-0.49	149	241
67	4.13	-0.50	145	242
71	4.05	-0.36	141	238
74	3.95	0.03	146	240
78	3.98	0.08	147	238
82	3.88	0.04	147	238
86	3.87	-0.03	148	239
90	4.07	-0.10	147	243
94	4.22	-0.27	147	244
98	4.46	-0.34	144	243
102	4.45	-0.19	143	242
106	4.54	-0.17	145	243
110	4.60	-0.39	146	243
114	4.72	-0.42	149	245
118	4.64	-0.65	149	247
122	4.65	-0.77	150	249
126	4.75	-0.98	155	251
130	5.23	-1.33	162	253
134	5.52	-1.50	164	254
138	5.54	-1.38	167	255

For Solid Ice Period

Insufficient Period for Analysis

Table 18: Tidal Constants for S2 Constituent (continued)

South Central Barrow Strait (Workhorse ADCP)

For Ice Free Period (Aug. 10, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
10	4.15	-0.90	161	237
14	4.33	-1.04	169	240
18	4.60	-0.94	176	245
22	4.91	-0.96	180	249
26	4.96	-1.06	177	247
30	4.84	-1.19	172	242
34	4.89	-1.14	170	240
38	5.01	-1.13	168	239
42	4.76	-1.02	169	237
46	4.33	-0.47	167	238
50	4.08	-0.29	165	237
54	4.10	-0.46	165	237
58	4.05	-0.67	165	240
62	4.06	-0.82	166	236
66	4.07	-0.72	165	239
70	4.12	-0.78	163	242

For Solid Ice Period

Insufficient Period for Analysis

Table 18: Tidal Constants for S2 Constituent (continued)

South Central Barrow Strait (Quarter Master ADCP)

For Ice Free Period (Aug. 11, 2010 – Oct. 9, 2010):

Depth (m)	Major Amplitude (cm/s)	Minor Amplitude (cm/s)	Orientation (degrees cc from East)	Greenwich Phase (degrees)
25	4.33	-0.74	167	247
33	4.47	-0.81	162	247
41	4.31	-0.77	157	243
49	3.84	-0.35	157	243
57	3.77	-0.08	154	240
65	4.27	-0.52	155	240
73	4.53	-0.92	157	243
81	4.45	-1.00	158	245
89	4.57	-1.12	160	246
97	4.55	-1.25	159	246
105	4.49	-1.36	159	244
113	4.42	-1.22	158	247
121	4.38	-1.24	160	248
129	4.26	-1.31	162	248
137	4.32	-1.16	164	252
145	4.44	-1.06	166	255
153	4.28	-0.92	168	261
161	4.03	-0.67	171	262
169	3.76	-0.42	173	257
177	3.36	-0.37	170	256
185	3.48	-0.39	170	256
193	3.68	-0.48	170	256
201	3.78	-0.36	175	255
209	3.58	-0.26	176	255
217	3.37	-0.20	168	252
225	3.60	-0.39	165	248
233	3.63	-0.35	163	248

For Solid Ice Period

Insufficient Period for Analysis

Table 19: Ice Profiling Sonar, Ice Draft Monthly Statistics South-Central Barrow Strait, August 2010 – July 2011

Year	Month	Ice Draft (m)		
		Mean	Maximum	Std.Dev
2010	August	0.11	15.70	0.74
	September	0.00	0.00	0.00
	October	0.22	14.86	0.63
	November	1.38	18.86†	1.42
	December	1.85	18.99†	1.84
2011	January	2.29	18.03	2.02
	February	2.59	19.31†	1.99
	March	2.05	19.77†	2.36
	April	0.82	11.37	0.97
	May	0.68	12.86	0.90
	June	0.03	12.08	0.25
	July	0.00	7.50	0.03

† Maximum limited by moored depth (29 m) and lock out range (10 m)

Table 20: Ice Profiling Sonar, Ice Draft Percent Frequency by Month
South-Central Barrow Strait, August 2010 – July 2011

	2010					2011						
Ice Draft (m)	August	September	October	November	December	January	February	March	April	May	June	July
Open Water	96.59	100.00	34.48	0.37	0.00	0.00	0.00	0.00	0.00	25.77	98.10	99.99
0.0-0.5	0.11	0.00	50.63	34.99	13.46	5.72	6.17	17.19	51.08	21.04	0.33	0.00
0.5-1.0	0.11	0.00	3.17	20.85	35.25	30.25	11.87	28.37	31.34	35.72	0.32	0.00
1.0-1.5	0.34	0.00	1.48	10.66	10.29	12.50	21.81	14.49	5.09	6.01	0.50	0.00
1.5-2.0	0.74	0.00	1.01	7.93	7.35	8.94	10.52	8.28	3.24	3.65	0.31	0.00
2.0-2.5	0.56	0.00	0.68	6.25	6.69	8.13	8.33	5.24	2.84	2.52	0.21	0.00
2.5-3.0	0.40	0.00	0.44	4.92	6.42	7.78	7.65	4.50	1.96	1.81	0.09	0.00
3.0-3.5	0.26	0.00	0.31	3.66	4.78	5.38	6.77	4.37	1.27	1.25	0.05	0.00
3.5-4.0	0.16	0.00	0.22	2.72	3.77	4.64	7.31	3.39	0.86	0.77	0.03	0.00
4.0-4.5	0.12	0.00	0.13	1.94	2.91	3.34	4.81	2.98	0.66	0.51	0.02	0.00
4.5-5.0	0.09	0.00	0.08	1.34	2.11	2.59	3.41	2.05	0.49	0.32	0.02	0.00
5.0-5.5	0.07	0.00	0.06	0.93	1.65	2.11	2.47	1.81	0.34	0.22	0.01	0.00
5.5-6.0	0.06	0.00	0.04	0.63	1.37	1.93	2.12	1.28	0.27	0.15	0.01	0.00
6.0-6.5	0.05	0.00	0.03	0.43	1.00	1.59	1.63	1.08	0.21	0.09	0.00	0.00
6.5-7.0	0.04	0.00	0.03	0.31	0.64	1.31	1.09	0.83	0.17	0.06	0.00	0.00
7.0-7.5	0.03	0.00	0.03	0.18	0.54	1.04	1.09	0.59	0.06	0.04	0.00	0.00
7.5-8.0	0.03	0.00	0.02	0.13	0.36	0.73	0.94	0.46	0.04	0.02	0.00	0.00
8.0-8.5	0.03	0.00	0.02	0.08	0.31	0.52	0.52	0.37	0.03	0.01	0.00	0.00
8.5-9.0	0.03	0.00	0.01	0.05	0.22	0.44	0.40	0.27	0.03	0.00	0.00	0.00
9.0-9.5	0.02	0.00	0.01	0.04	0.15	0.33	0.29	0.23	0.01	0.00	0.00	0.00
9.5-10.0	0.03	0.00	0.01	0.03	0.08	0.22	0.20	0.17	0.01	0.00	0.00	0.00
>=10.0	0.12	0.00	0.03	0.08	0.56	0.53	0.57	2.03	0.01	0.01	0.00	0.00
Missing	0.01	0.00	7.07	1.49	0.09	0.00	0.04	0.00	0.00	0.01	0.00	0.00